FAMOUS SPACESHIPS

OF FACT AND FANTASY

... And how to model them

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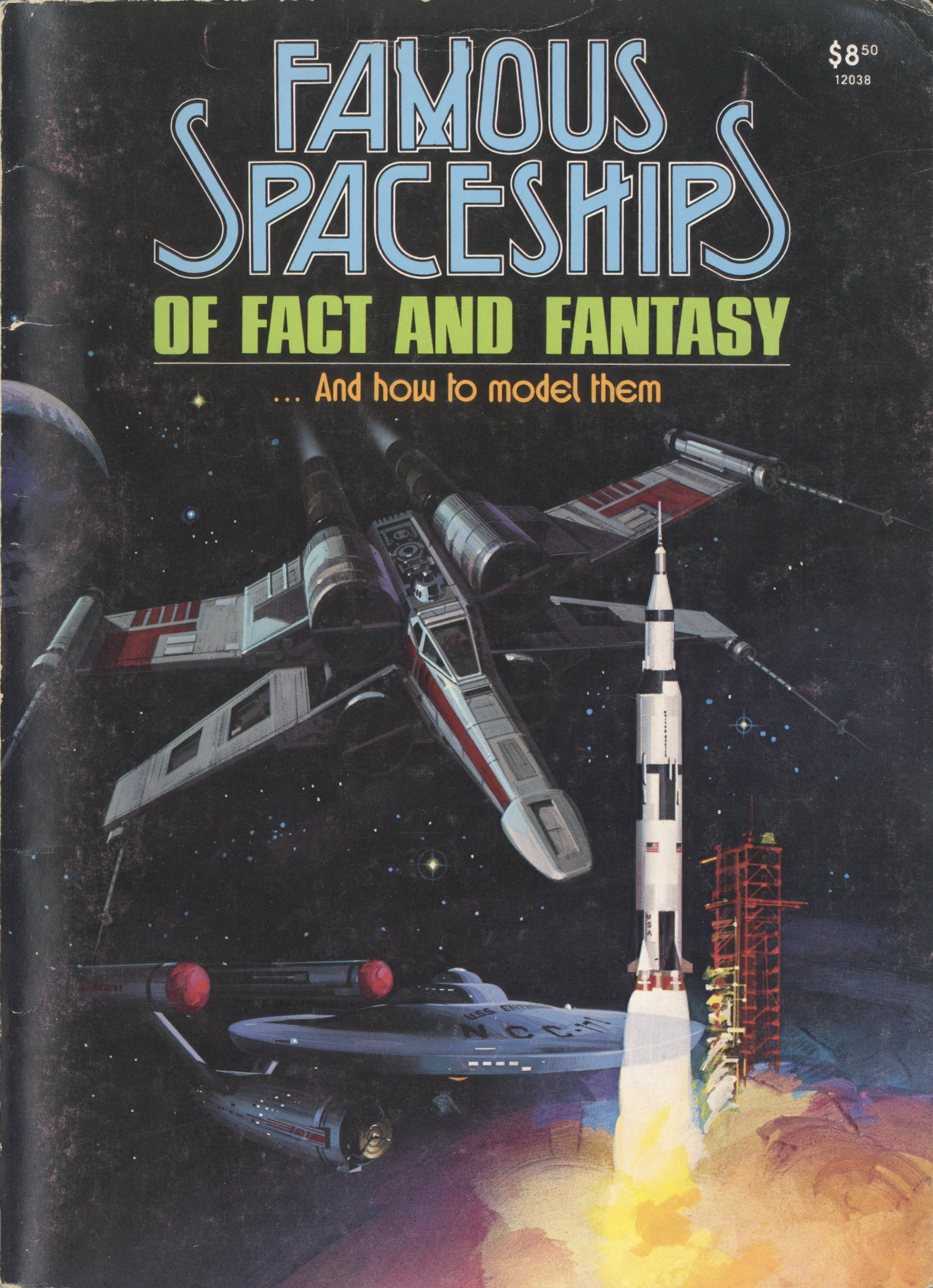

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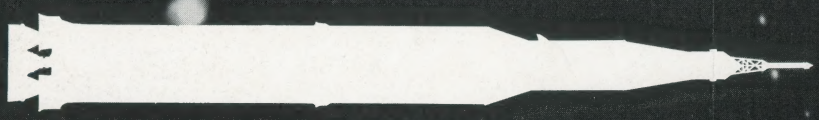

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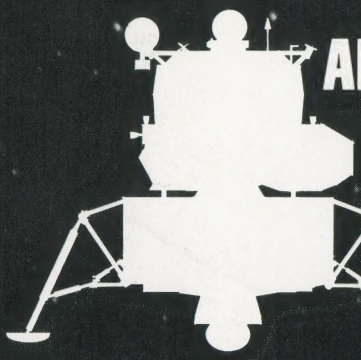

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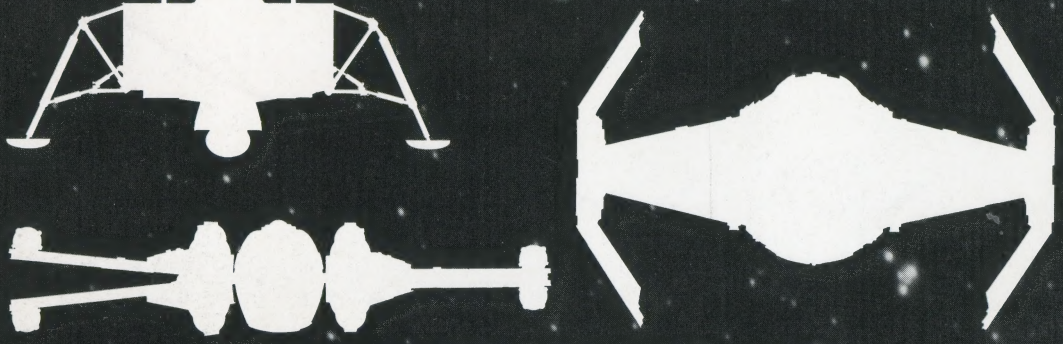

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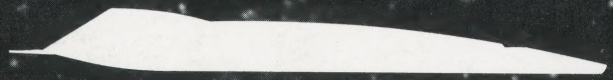

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FAMOUS SPACESHIPS OF FACT AND FANTASY

EDITED BY HAROLD A. EDMONSON

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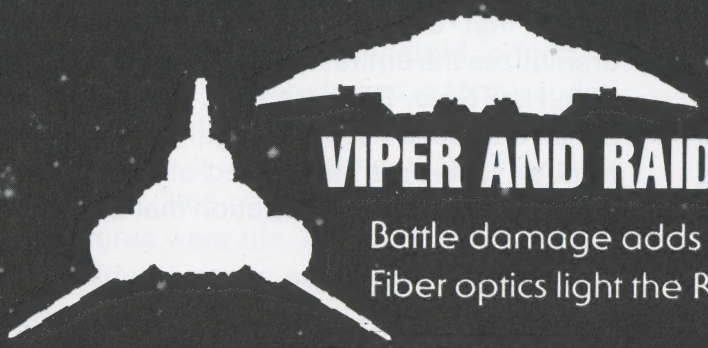

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Milky Way in Sagittarius: *Astronomy* magazine

A BIT OF PERSPECTIVE

GEORGE ELRICK

SOME of the spacecraft presented in the following pages are "real;" others are fictional. Whether they stem from science fiction authors' fantasies or scientists' calculations, the make-believe and the actual are so closely related—with the exception of warp drive and supralight jump capability—as to be joined at the hip. Science fiction draws upon real life; real life, in turn, draws upon science fiction and fantasy. The projections of Jules Verne and H. G. Wells have largely come true. Arthur C. Clarke's proposals for artificial satellites, made in the 1930's, saw fruition on October 4, 1957, when Sputnik I beeped across the heavens.

Generally speaking, what's fictional today will be realizable (for better or worse) tomorrow. The laser weaponry of *Star Wars* and *Battlestar Galactica* isn't even a step removed from that of hunter-killer satellites currently on drawing boards. An emission weapon like *Star Trek's* phaser may well be developed before youngsters now entering kindergarten graduate from high school. The same can be said regarding photon torpedoes or their equivalent. The principles governing ion engines have been known since World War II. Nuclear fusion propulsion engines are no longer considered outlandish. Odds are that force field and deflector systems are being explored at this time in secret private or government laboratories around the globe.

The main point of contention between what's regarded by science fiction writers as possible and by scientists as impossible is faster-than-light travel. According to Einstein (and his theories have been experimentally verified many times), nothing in the universe can surpass lightspeed. An object's mass increases as its velocity increases, so that its mass becomes infinite at the speed of light. This fact need not bother readers and viewers of science fiction, because all art forms necessarily involve taking some liberties with the "real world." No one objects if a play or movie that actually lasts an hour or two dramatizes the entire life of its hero. If Captain Kirk, Han Solo, Princess Leia, and other fictional characters zip from galaxy to galaxy through faster-than-the-speed-of-light jumps, so be it. It's a convenient fiction that keeps the adventures moving.

Still, a competent science fiction writer is usually careful to avoid violating laws of nature without good artistic reasons. A scriptwriter who causes spaceships traveling through a vacuum to decelerate when they run out of fuel is flouting laws of inertia known to western man for centuries. A director who insists that the sounds of explosions can be heard in a vacuum similarly violates elementary facts of nature. A good part of the pleasure of science

fiction comes from its "let's pretend this really could happen" attitude: The writer who ignores too many scientific facts isn't playing by the rules accepted by science fiction audiences. He may present entertaining stories, but these are now fantasy, not science fiction.

Of course, in a society in which technology changes rapidly, ideas about what could happen and what could be possible also change rapidly. The design of fictional spaceships is a case in point: they have changed radically over the years. In this case, fiction has closely followed contemporary trends in popular design and has attempted to keep current with the designs of U.S. and Soviet spacecraft. Whether oblate (roughly spheroid in form) or prolate (roughly cigar-shaped in form), spaceships, prior to the streamlining of the Chrysler automobile in 1933, tended to resemble Christmas tree ornaments. Protuberances and filigree were rife. An examination of early Buck Rogers comic strips confirms this. Following the public's infatuation with gently curved tear-drop shapes, artists began to depict most spaceships as elongated fountain pens. This situation prevailed for 15 years. After World War II, and actual space probes by NASA and the Soviet Union, many fictional spacecraft reverted to shapes prevalent before 1933.

Why? Because science fiction writers and artists recognized that because there is no atmosphere in outer space, there is no need for streamlining. A spaceship contoured like an Easter basket travels just as fast as one structured like a pointed pencil. Streamlining is necessary, though, for those spaceships that are meant to operate in planetary atmospheres as well as outer space. That's why some of the recent fictional spaceships in this book are streamlined and some aren't.

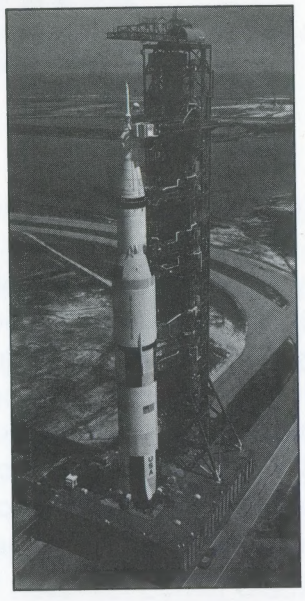
Whatever its design, each modern fictional spaceship is equipped with an extremely sophisticated guidance system featuring sensor screens, long distance radars, etc. This reflects the enormous complexity of navigating artificial satellites, planetary probes, and, of course, the Apollo moon missions. In the early days of Buck Rogers, Flash Gordon, and Brick Bradford, spaceships were steered by levers similar to those used on bulldozers.

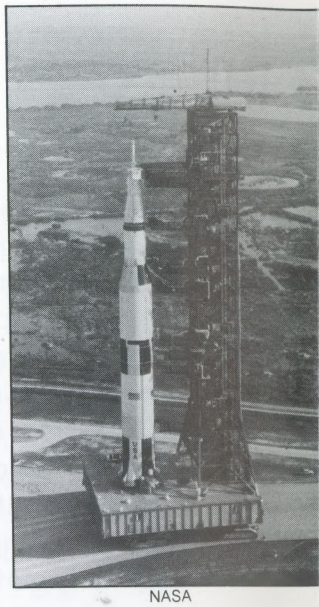
Thus it goes, fiction influences reality; reality influences fiction. This book attempts to show the best of both worlds.

George S. Elrick, author of the best-selling The Science Fiction Handbook for Readers and Writers (Chicago Review Press, 1978), is a noted SF writer and expert, and a member of the Science Fiction Research Association.

America's unparalleled moon rocket...

SATURN V





NASA

Space flight offers many contrasts: Months before launch date, the Saturn V for Apollo 10 that carried astronauts Stafford, Young, and Cernan at speeds exceeding 25,000 mph was carried to the launch complex at speeds no faster than a slow walk. Roadbed is 7 feet thick.

JAMES E. OBERG

SUPERLATIVES fail when it comes to describing the Saturn V moon rocket. It was the biggest space booster in the world, and bigger ones may never be built. Combined with its awesome power was delicate precision and solid reliability — all attributes necessary for the rocket which was to send men to the moon.

Imagine a machine with 40 million horsepower. Imagine a machine which guzzled fuel faster than all operating American automobiles combined. Imagine a machine the very *sound* of which could smash unprotected human bodies for hundreds of yards around. Imagine a machine which took 10,000 man-years to build but which was used for only 10 minutes. That's Saturn V.

Fifteen Saturn V rockets were built during the 1960's for the Apollo moon program. After two unmanned flights in 1967-1968, Saturn V's carried 10 manned Apollo expeditions in the years 1968-1972. One additional Saturn V placed the giant Skylab space station in orbit in 1973, and the other two served as backup vehicles and then were placed on exhibit in museums (actually, of course, *outside* the museums!).

The Saturn V was the largest member of the Saturn series of rockets, which were conceived by the rocket team of Wernher von Braun at the Huntsville (Ala.) Redstone Arsenal (later, under the National Aeronautics and Space Administration, it became the George C. Marshall Space Flight Center). The smaller Saturn I began testing in 1961 and launched test Apollos into earth orbit. The manned Apollo VII, the three Skylab visits, and the Apollo-Soyuz linkup were launched atop the Saturn I, which had about one fifth the power of the Saturn V.

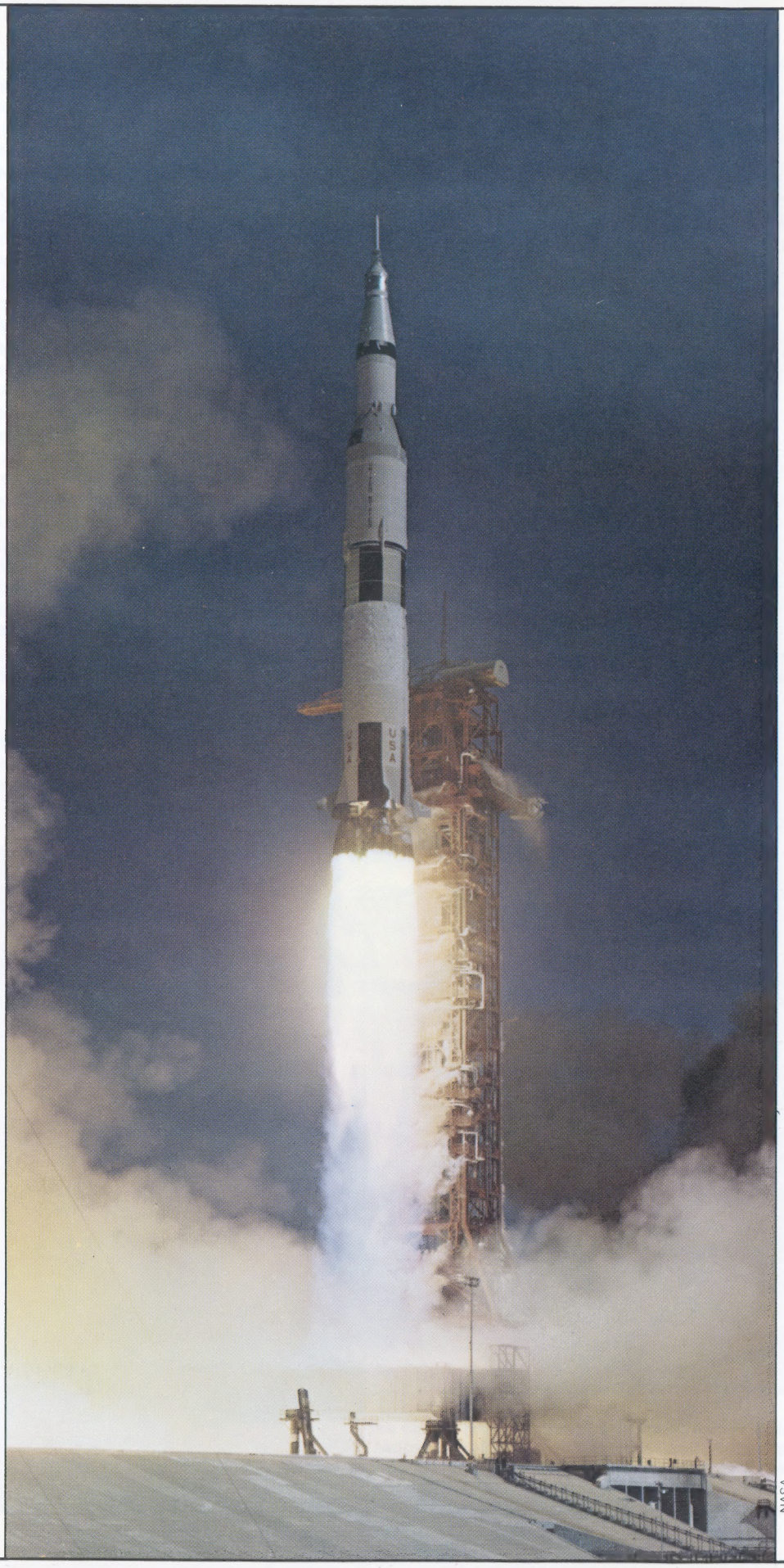
A Saturn V rocket stood 363 feet high. It was 33 feet wide at its base, excluding fins. It had three stages, of which only the third stage went into orbit with the Apollo spaceship. After a few hours of navigational checks, the third stage was fired again to propel the Apollo outward and upward towards the moon.

STAGE 1 (S-1C): For the first two minutes of flight, the Saturn was lifted by five giant F-1 rocket engines, the most powerful ever built anywhere in the world. Kerosene and liquid oxygen were burned at a rate of 10,000 pounds per second. Its job done, the first stage fell back to earth and tore apart in the atmosphere, with pieces splashing into the Atlantic 300 miles from Cape Canaveral, Fla.

STAGE 2 (S-11): Five J-2 engines pushed the remaining vehicle higher into space, using a high-efficiency propellant supply based on liquid oxygen and liquid hydrogen. This stage burned for three minutes before falling back to earth and disintegrating in the upper atmosphere 5,000 miles from the launch site.

STAGE 3 (S-1VB): A single J-2 engine powered the third and final rocket stage. Atop this stage was the computer unit which provided guidance to the entire three-stage rocket. This stage entered earth orbit, after which the rocket was shut down, usually with about half its fuel remaining. The third stage stayed in orbit several hours while careful navigational observations were made by the Apollo crew, the third-stage computer, and Mission Control at the Manned Spacecraft Center (now the Johnson Space Center) at Houston, Tex. With updated targeting information loaded into the computer, the third stage was fired again for the final lunge into deep space. The separation of the Apollo Spacecraft was next in the moon-flight sequence. This is described in detail on page 19. No watery grave awaited the spent third stage; space controllers aimed it smack into the

Five engines that produced a total maximum thrust of 7,500,000 pounds lifted Apollo 15 space vehicle from Pad A, Launch Complex 39, Kennedy Space Center, Fla., at 9:34:00. 79 a.m. (EDT), July 26, 1971.



NASA

moon to create artificial "moonquakes" for scientific instruments to monitor (on the test missions, however, the third stage was simply aimed into space to assume a solar orbit).

The flight profile of the Saturn rocket was, in theory, a simple one. But since nothing assembled by the minds and hands of men ever seems to work perfectly, numerous problems did arise. Every single Saturn rocket was successful in its mission, but often it had to rely on redundancy and the "safety margin" which designers had built in.

The first test flight of the Saturn V from John F. Kennedy Space Center, Fla., on November 9, 1967, went *almost* flawlessly. The only minor casualty was TV newsman Walter Cronkite, whose television studio — hastily constructed at the press site 3 miles from the launch pad — fell over on him during the powerful blast-off. The rocket itself, in a bold "all stages live" gamble, worked just about as planned.

Not so the second unmanned test the following April. During second-stage flight, severe "pogo oscillations" tore pieces of the rocket loose. Two of the five second-stage engines failed, yet the flexible control computer tilted the remaining three engines slightly and burned them for a minute longer, compensating for most of the loss. And although the third-stage rocket burned during the ascent, it failed to burn the second time after coasting through space for several hours.

Rocket engineers worked furiously to eliminate the problems. "Pogo," a fierce up-down oscillation, was caused by the surge of fuel in the feed lines — surging which initially was set off by rocket vibration but which snowballed when each surge fed extra fuel into a succeeding surge a second or two later. Uncontrolled,

NASA

(Above) Giant Crawler/Transporter carried Saturn V for Apollo 15 and the Launcher Umbilical Tower from Vehicle Assembly Building to the Launch Complex. An ambitious modeler could build these structures from styrene. (Right) Fuel was delivered through piping from the tower.

Pogo could (and did) tear rockets apart. Special flow controllers and reservoirs were designed and installed in the next Saturn V. The J-2 failure was traced to vibration of fuel lines, in which metal fatigue caused small pipes to break off. The pipes were made more flexible.

The fixes apparently worked, because the Saturn V's on the next five missions performed perfectly. Even when the rocket was hit by lightning a few minutes after launch during Apollo 12, the controller computers continued to guide the spaceship on its course.

At 13:13 Houston time, April 11, 1970, Apollo 13 blasted off. It was to take its place in the history books as the only moon flight that failed. But many hours before the explosion (see page 21) that nearly doomed the astronauts to a lingering space death, the Apollo 13 Saturn V suffered the most serious rocket failure of any American manned space shot. One of the five engines of the second stage failed, and the remaining engines in the second and third stages had to burn longer to compensate. Luckily, a fuel reserve had been included, and the launch toward the moon was successful. Fate, or just plain bad luck, clearly was out to get Apollo 13.

Five more Saturn V's were subsequently launched, each carrying more and more weight as design improvements were added and safety margins were carefully reduced where they proved to be too generous. Lunar payloads increased from 87,382 pounds on Apollo 8 to 107,221 pounds on Apollo 17. The final Saturn V flight used only two stages to put Skylab into an earth orbit. The burned-out second stage remained in orbit for a year, trailing behind the space station but gradually slipping back to earth under the weak air drag 200 miles high. For a few days, observers on earth feared it might hit the ground intact and cause property damage or human casualties. But, eventually it plunged harmlessly into the North Atlantic, out of sight.

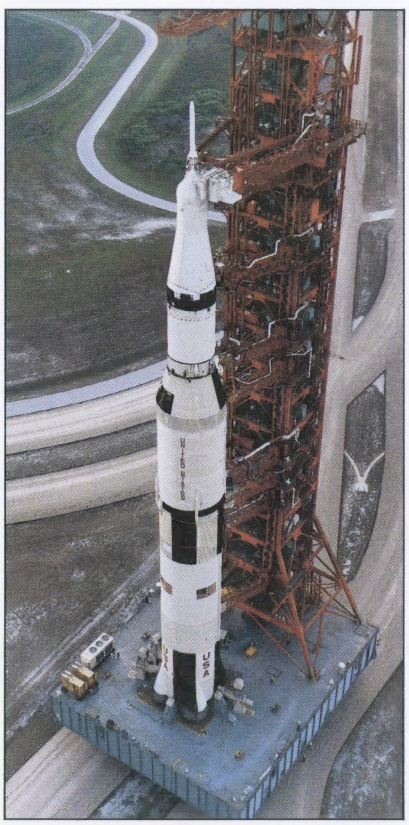
STAGES, SOUVENIRS, AND THE SOVIETS

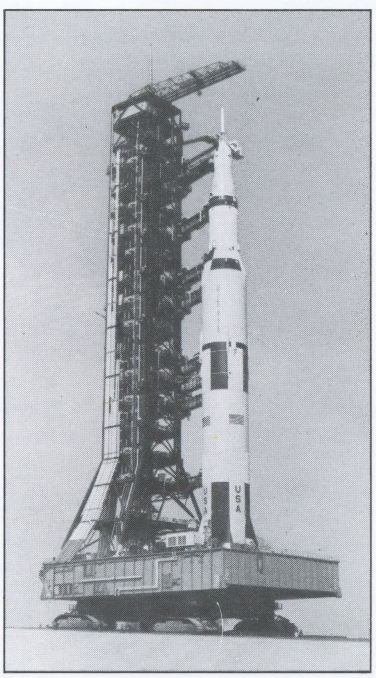
The three stages of the Saturn plus the rocket engines and other components were built across the United States and shipped by barge, airplane, and truck to Kennedy Space Center. Stage one was built by Boeing at Huntsville and Michoud, La. Stage two was built by North American at Seal Beach, Ca. Stage three was built by Douglas at Huntington Beach, Ca. Rocketdyne built all the engines at Canoga Park, Ca.

Once the stages arrived in Florida, they were rolled on flatbed trailers into the giant Vehicle Assembly Building (the VAB). Standing 550 feet high, the VAB was the largest building in the world when it was constructed. Inside, four separate Saturn rockets could be assembled, each on its own movable pedestal in its own assembly bay. (In practice, only two of the bays were actually used, with the others in reserve in case of accident or additional launch requirements.) Once assembled, the three-stage Saturn V and its Apollo spaceship were transported vertically on the pedestal to the launch site 3 miles away.

A giant crawler tractor moved the pedestal carrying the unfueled Saturn along a dual-lane gravel road 130-feet wide at a speed of 3 mph. Once the pedestal with the Saturn was placed on the launch pad, the tractor slipped out from underneath and crept away to a safe distance, always ready to be called back in case the Saturn had to be returned to the VAB for repair, replacement, or refuge from hurricanes.

Launchings were eyewitnessed by tens of thousands of people from all over the country and by millions on live





NASA

(Left) Nine ramps gave access to each level of Apollo 15 before launch. (Above left) Saturn 505 carried Command Module "Charlie Brown" and Lunar Module "Snoopy" into lunar orbit during Apollo 10. (Above right) Plastic shrouds protected Apollo 11 thrusters from salty, humid Florida atmosphere.

TV. Half a million Americans gathered in Florida in July 1969 to see the sixth Saturn V carry Apollo 11 astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin Jr., into space. Crowds dwindled on later "routine" missions, with an upsurge for the final and most spectacular moonshot, Apollo 17. This twelfth Saturn V booster was the only one to be launched at night, and it flared like a giant torch in the midnight skies over the East Coast.

Saturn V rockets left scattered souvenirs across the face of the earth and moon. A German freighter was showered with metal fragments from the Apollo 11 launch, and stories filtered out of the jungles of South America and Africa about aluminum sheets which fell from the sky and were worshipped as gods by the natives. Five new craters were dug on the moon by Saturn V third stages hitting the surface at 6,000 mph and splattering fragments across hundreds of square miles of "lurain" (lunar terrain).

The white paint with black patterns on the Saturn V booster was as much a matter of tradition as an engineering requirement. Fins were lettered so that tracking films could tell which way the booster twisted, while the general pattern was helpful in visual tracking. Mainly, however, the livery was a carryover from the V-2, Viking, Redstone, and Jupiter rocket days. The Saturn V was painted white and black because that was the way Dr. Wernher von Braun liked it (the paint layer weighed almost a ton and cost a few hundred pounds of payload capability, but the Saturn V could carry it without any problem).

Space operations in the Space Shuttle era do not require the weight-lifting power of the old Saturn V's. Instead, space payloads can be built in smaller modules and brought into orbit separately, then linked together. The total payload capacity of the Space Shuttle is about one-fourth that of a Saturn V, but at one-tenth the cost.

The seeming wastefulness of dropping multimillion-dollar Saturn rockets into the oceans was a popular theme during the Apollo program, but critics did not realize what rocket designers had come to know: Throwing away the booster stages was actually the *cheapest* way to fly. Only major advances in space technology, spurred by the Apollo program, allowed space engineers to advance to the cheaper reusable Space Shuttle.

How can throwing away a booster be cheaper? Most of the answer lies in the simple fact that the immense prices quoted for Saturn rockets (180 million dollars each) involved primarily the manhour cost of checking out the rocket and preparing it for flight. The actual cost of the metal in the rocket was a small percentage of the final cost.

The engineers certainly did something right. They built an unprecedented space machine, using technologies never before tried (and many not even imagined when the project began), and they did it on schedule and under budget. The Saturn V never failed to deliver its payloads into space with the planned velocities and headings. And as their experience and confidence grew, these rocket builders added new and more powerful features to each subsequent Saturn V.

The American success must also be contrasted with the failure of the Soviet Union to build a similar rocket. Soviet space planners were equally committed to sending Russian cosmonauts to the moon, ahead of Apollo, but their technology base failed them and their program faltered. After the early Apollo successes, the Soviet man-to-the-moon program was cancelled and covered up, and Moscow began a new propaganda tack of claiming that it had never really meant to send men to the moon, anyhow. This sour grapes whine was accepted in some Western circles because it coincided with old antispace prejudices, but the Soviets were lying.

In fact, a giant Soviet space booster was built with twice the liftoff thrust as the Saturn V but, because of inherent design deficiencies, with only about the same payload capacity. Despite several reported launch attempts in the 1969-1972 period, the Soviet space rocket team was unable to carry off a successful flight. The secret rockets crashed in flames during the same years that Saturn V's were blazing the American trails to the moon. It's a chapter of Soviet space history that Moscow never talks about. And it underscores the brilliant engineering work that made the Saturn V possible.

Saturn V's engines are silent now. Fragments carpet the Atlantic and the face of the moon. Surplus equipment lies on the ground at space museums at Johnson Space Center, Marshall Space Flight Center, and Kennedy Space Center. But even today, visitors to these rockets feel an incredible sense of awe at the size and power of the Saturn V's, which in real life blazed paths across the skies and which burned their way into history books.

Apollo Booster Specifications: Saturn 1B

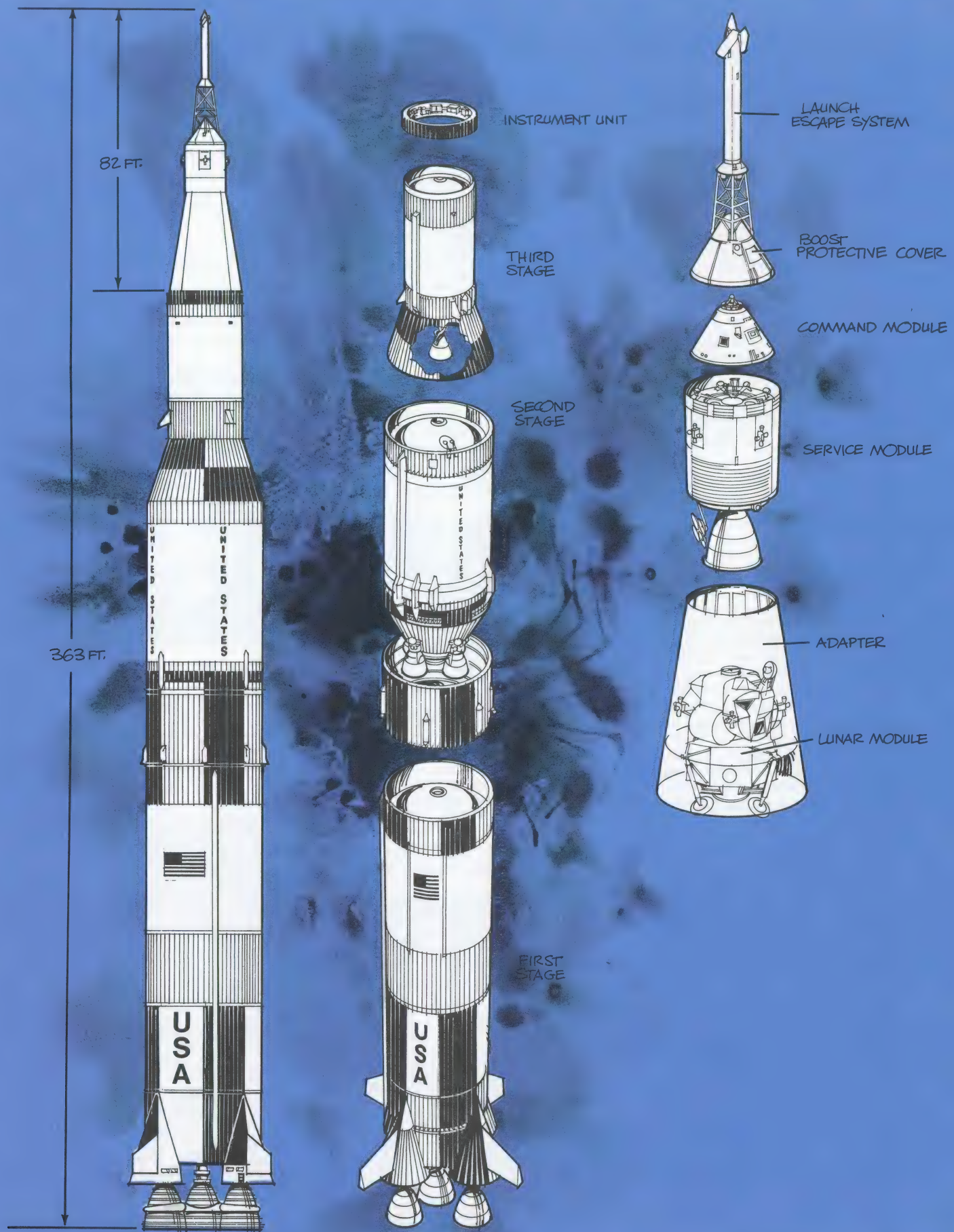
Height (with Apollo)	224′
Maximum diameter	21′-7″
Weight (flight-ready)	1,300,000 pounds
Stages	2
Propellants — 1st stage	RP1 (kerosene), liquid oxygen
2nd stage	Liquid hydrogen, liquid oxygen
Maximum payload (low earth orbit)	40,000 pounds
Maximum 1st-stage thrust	1,600,000 pounds
Engines — 1st stage	8 H-1
2nd stage	1 J-2
Saturn 1B horsepower	24,000,000

Apollo Booster Specifications: Saturn V

Height (with Apollo)	363′
Maximum diameter	33′
Weight (flight-ready)	6,200,000 pounds
Stages	3
Propellants — 1st stage	RP1 (kerosene), liquid oxygen
2nd stage	Liquid hydrogen,
and 3rd stage	liquid oxygen
Maximum payload (low earth orbit)	270,000 pounds
Maximum payload (trans-lunar injection)	100,000 pounds
Maximum 1st-stage thrust	7,500,000 pounds
Engines — 1st stage	5 F-1
2nd stage	5 J-2
3rd stage	1 J-2
Saturn 5 horsepower	160,000,000

Saturn V Construction Record:

Total vehicles constructed	15
Unmanned flights	2
Manned Apollo missions	10
Skylab orbital booster	1
Backup units (later used as exhibits)	2


82 FT.
363 FT.
UNITED STATES
UNITED STATES
USA
INSTRUMENT UNIT
THIRD STAGE
SECOND STAGE
UNITED STATES
FIRST STAGE
USA
LAUNCH ESCAPE SYSTEM
BOOST PROTECTIVE COVER
COMMAND MODULE
SERVICE MODULE
ADAPTER
LUNAR MODULE

Beginner's guide to plastic kit modeling

KIT: Apollo-Saturn V
MANUFACTURER: Airfix, England, Kit No. 09170-5
SCALE: 1/144
DIMENSIONS: 30⅛″ high (without display base); 5¼″ diameter at fins; Display base—4¼″ x 5⅞″ x 1″ high.

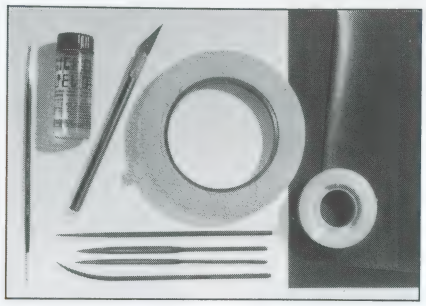
Harold A. Edmonson

THE AIRFIX SATURN V is an ideal model for the beginner. The parts are large and easy to handle and assemble. The finer techniques of modeling — such as seam-filling and sanding — can be learned on the broad surfaces of the Saturn's stages. Spray-painting techniques can be developed using the Saturn. One of the few places where the beginner might run into trouble is with the masking and painting of the ribbed surfaces, but then again, it may be just as well to meet this demanding phase of modeling head-on right from the beginning.

When the work is done and all the stages are mounted (not unlike the manner in which the real stages were gathered at Kennedy Space Center and assembled in the giant VAB), the finished Saturn is an impressive replica standing 30 inches tall and giving little hint of the relative ease with which the various components were constructed.

Not only will the beginner have one of the most exciting models he'll ever build, but he'll have learned basic modeling techniques to assist him in building more difficult models, including ones in this book. The only drawback to the Airfix Saturn is that it is priced in the higher range, but if you're willing to take from the Saturn kit what it offers you, you'll not only have a fine display but be a much better modeler.

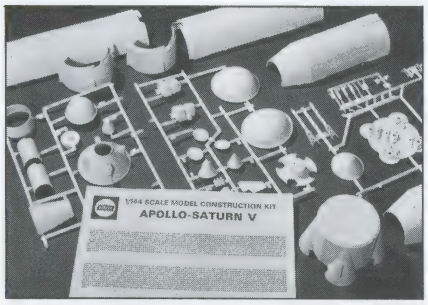
Before I began construction, I made sure I had my basic hobby tools before me. **These included a hobby knife (X-acto with No. 11 blade), a set of jeweler's files,**



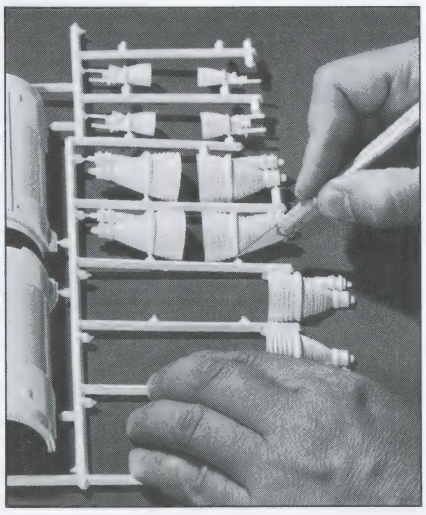
wet-or-dry sandpaper (No. 400 and No. 600), masking tape, Scotch Magic Transparent Tape, and liquid cement for plastics with a paint brush to use for application. Other supplies would be introduced during the construction process.

The major steps in building the Saturn are the same as those that should be applied to all models in this book — and plastic models in general.

First, carefully read the instruction sheet. Look at the sprue tree and identify



the parts; don't remove any parts until you understand where they will fit in the finished model. Remove the plastic parts only as they are needed for test-fitting, construction, or prior painting. Do not break the parts off the sprue tree with your fingers; you may lose a small chunk of the part on the sprue tree. **Cut the part away**



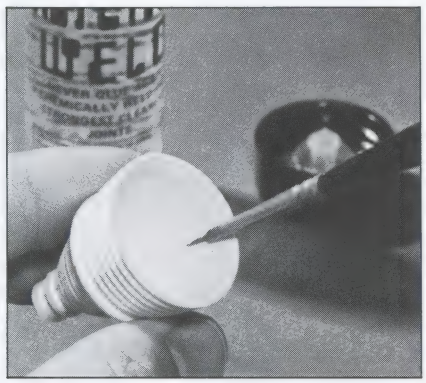
with your knife (or with a razor saw if the attaching plastic is very thick). You can always file or sand any portion of the sprue still attached to the part.

Test-fit all parts before doing any cementing. Make sure the pegs and tabs of one part fit the holes or slots of the next part. Use the hobby knife or files to trim and clean the parts until they fit snugly together.

Following the order of assembly shown in the instruction sheet, I test-fitted the lower part of the first stage — which included the stability fins and five F-1 rocket engines. **When I test-fitted the two rocket cone halves, I noted some small gaps or**

holes where the halves butted together — the plastic had not completely filled the mold when the part was made. This was one of the few faults I was able to find with the craftsmanship of the kit.

The first parts I cemented were these same F-1 engines. **I held the halves tightly together with the fingers and thumb of**



one hand while I applied liquid cement to the join line with the brush. I placed most of the cement on the inside of the join line, merely touching the brush to the line at several points and allowing "capillary action" to flow the cement the entire length of the join line.

I used liquid cements to assemble my Saturn V. Today many adhesives are avail-

able to the modeler. The best known are still the tube-type and liquid-type cements for styrene plastic that have been available for many years. These are basically solvents that melt the adjoining surfaces of plastics so that the styrene fuses together.

I chose liquid cement over the tube type because it dries faster, permitting the modeler to start work sooner on the next step in the construction process. Although care must be taken with all cements, liquid cements are not normally as messy as tube cements.

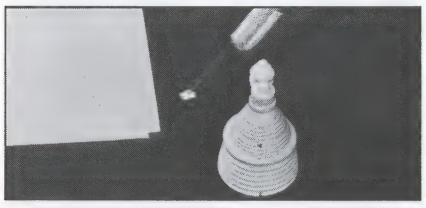
A word of caution on the use of plastic cements: The plastic is softened by both the liquid and tube types, so both need adequate time to cure and dry when used on key structural parts or parts which later will be subjected to the weight of other parts. Wait at least overnight and up to several days before applying any stress to these parts.

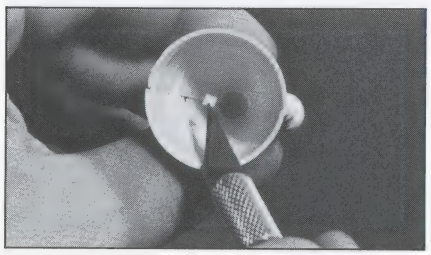
In addition to the plastic cements, there are many brands of fast-setting cyanoacrylate adhesives (ACC) plus household adhesives like white glue. I did not use the ACC products for several reasons: Most set up and dry immediately, and therefore, are unforgiving of assembly errors; they require extreme care in handling and application — their fumes can irritate the eyes and contact with skin can cause burns (and even cause fingers to stick together); and they are much more expensive than cements for plastics. In short, the Saturn project was attractive because of its suitability for beginners, and ACC's are not for beginners.

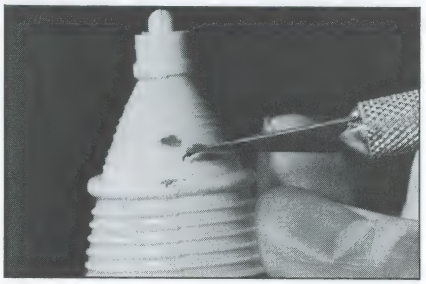
(More about the uses of ACC's will appear in following chapters.)

Back to our F-1 rocket motors: After cementing all five engines, it was apparent that the cones of several of the engines had at least one gap somewhere along the join line. The first step in correcting this problem was to fill in behind the gap with a small piece of plastic. Sheet plastic, available at most hobby shops, would be ideal for this purpose, as would flat pieces of scrap plastic.

I cut small squares of plastic from the styrene sheet and positioned them inside the cone behind the gap. A touch of liquid cement secured them in place. I found that the piece of plastic alone was enough to reasonably disguise the flaw, and in keeping with the theme of the Saturn as a beginner's project, there would be no need to go any further. **However, perfectionist modelers would want to fill in the surface of the gap with a small dab of filler putty.**







Careful filing and sanding would then be required.

Although I tried to slightly flex the F-1 halves to align them perfectly, a ridge line nevertheless formed in certain places along the join line. **I employed the tip of my flat file to remove some of this ridge**

and even used my round or rattail file to reach between the ribs of the cone.

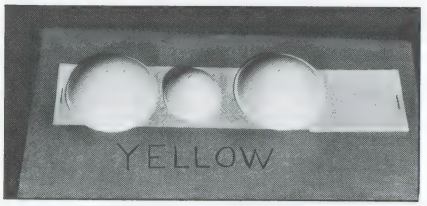
The appearance of gaps in the cones of the F-1's led me to think about the second stage J-2's. I jumped ahead of the construction sequence and test-fit those halves. Happily gaps did not appear. I went ahead and cemented the halves together for a reason: Because all the rocket engines would be painted silver, I felt it would be easiest to paint them all at one time before assembly. Therefore, I completed assembly of all the rockets and attached them to a cardboard sheet to await painting. I folded over some masking tape to give the effect of two-sided tape and placed it on the cardboard to hold the parts.

I also placed the stability fins on the cardboard (later I'd use clothespins during painting). My test-fitting had indicated the fins would fit snugly without unsightly gaps requiring putty. Therefore, I could paint them before assembly, which would be easier than painting when attached to the first stage.

I resumed test-fitting by placing together the large cylindrical halves for stage one and stage two. Dome-like pieces represent the tops of fuel tanks and, in effect, form the tops of stage one and stage two (and also stage three). Because these pieces fit between two rims cast on the inside of the cylinders, they must be inserted before the halves can be cemented, and, therefore, should be painted before any assembly is done.

My research showed that these domes would best be painted yellow, which is the color of the actual cross-member assemblies and bracing visible at the top of stages one and two. An interesting project for the advanced modeler would be to scratchbuild the bracing that is actually found at the top of these stages, but for my purpose, I used the domes as intended in the kit.

I made up two more pieces of cardboard-with-tape to hold the various parts.



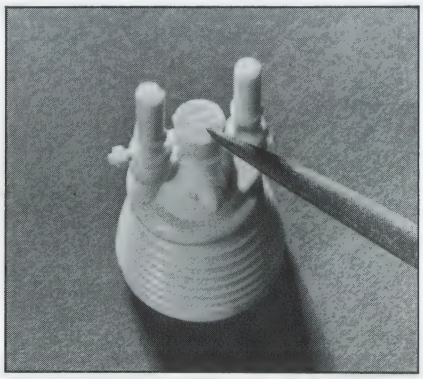
On one I placed the domes to be painted yellow. On the other I began placing all intended for white paint. Before placing the domes, I filed and smoothed the circumference edge.

The rocket motors for stage one are installed in a flat engine-mounting plate that in turn is inserted as the bottom of stage one. This plate should receive white paint. Cone-shaped pieces are the engine mounting structures for stages two and three, and these fit inside rims just as the cylinder tops do. Therefore, the pieces must be installed at the time the stages are assembled and should be pre-painted. My research showed that silver is the proper color.

The second-stage engine-mounting structure actually consists of a cone and

a flat plate; I cemented them together at this time. (This flat plate is a part that doesn't exist on the Saturn. A modeler who wants to omit it, however, will have to retain the center section as a support for the center rocket motor.)

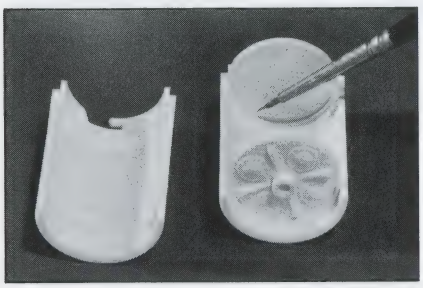
Before I placed the mounting structures on my "silver" cardboard, I test-fit the J-2 rocket engines to them. **A molding seam showed on that surface area of the J-2**

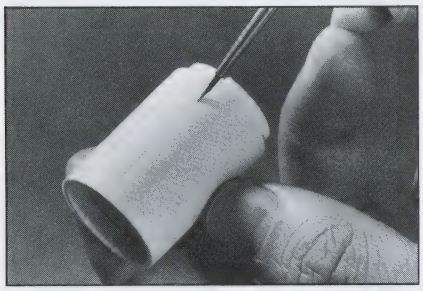


that would mate to the mounting structure, so I filed it flat.

By this time I was gathering a number of parts that would require silver paint, so I decided to see if I couldn't accomplish all the silver painting at one time. I studied the instruction sheet and gathered other silver parts. Some of the parts, such as the Service and Lunar modules, were in halves, so I assembled them at this time.

The cross members were inserted in one Service Module half and cemented in place. After a drying time of several min-

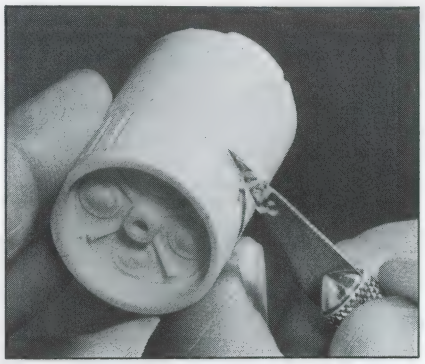




utes was allowed, the other half was joined and liquid cement was placed along the join lines.

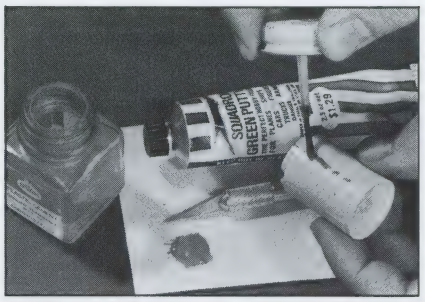
I inspected the SM after the cement had dried and found a small ridge along the join line, caused by (1) the halves not matching perfectly, and (2) a bead of liquid cement that had melted the plastic, popped above the surface, and dried. Ridge lines are common occurrences in plastic modeling; some modelers even strive for the bead of cement along the join line as assurance of complete bonding.

To remove the ridge, I placed my hobby knife on edge and scraped the blade along the join line. This technique, called adzing, is widely used to achieve a smooth surface at join lines. If the lines



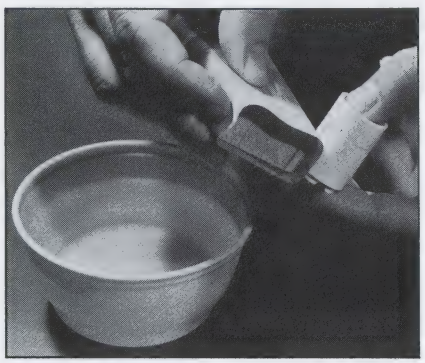
still aren't perfectly smooth, or there is a gap at some point, the modeler can fill the seam with putty.

I used a small quantity of Squadron Green Putty, available at many hobby stores, along the seam, spreading it with my hobby knife (a wood stick also can serve as a spatula). **If the Green Putty sets up too quickly, "cut" it and work it into**



place with a small quantity of Testors (liquid) Plastic Cement No. 3602.

Wait at least 30 minutes for Green Putty to dry. Wait much longer for thick applications to dry, although it is best to build up thickness through several applications. A large outcropping of the putty can be filed. **Once close to the seam, use No. 400 and No. 600 wet-or-dry sandpaper (or Flex-I-Grit) dipped in water to sand the seam**



smooth. Back the paper with a piece of wood to help maintain the curved contour of the part.

Next, I assembled the Lunar Module halves and trimmed and filed join lines where needed. The landing legs were cemented in place, and the LM joined the other parts on my "silver" cardboard.

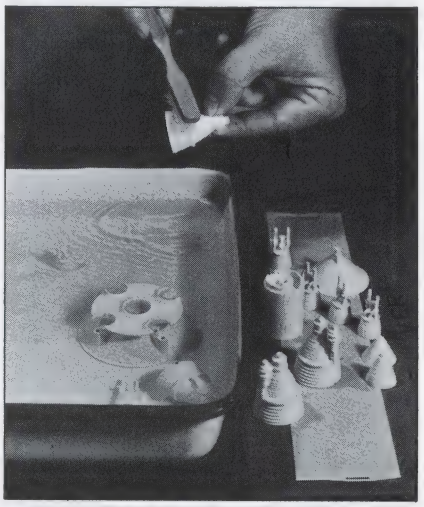
Some of the remaining pieces included the Apollo capsule and escape rocket. The capsule would be painted silver, so after sanding some rough edges, I merely set it next to the other silver parts. The main heat shield would be painted a different color entirely, which would be done later with a brush. Since the capsule and heat shield ultimately would be cemented together, I saw no real reason to paint the three astronaut figures or insert them in the capsule.

I assembled the escape tower at this time, including the cone that fits over the Apollo capsule, and placed it by the white parts.

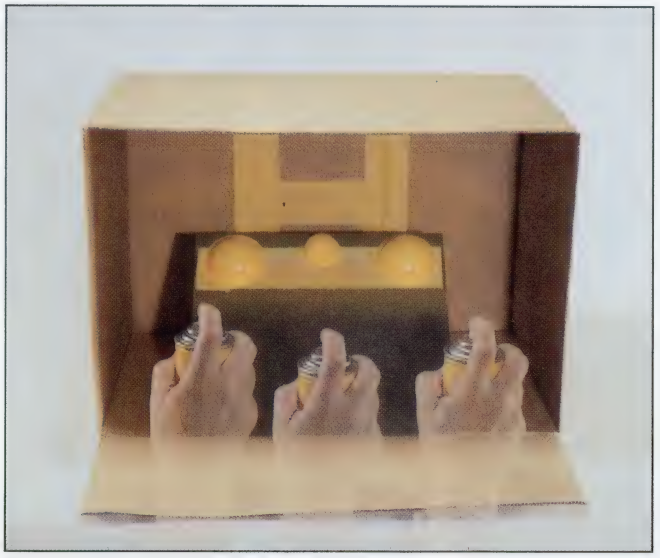
Although I had three cardboard sheets holding the parts that would be painted silver, white, and yellow, I could have painted *all* the parts a flat white at this point. The flat white would serve as an undercoat and would reveal imperfections in the parts.

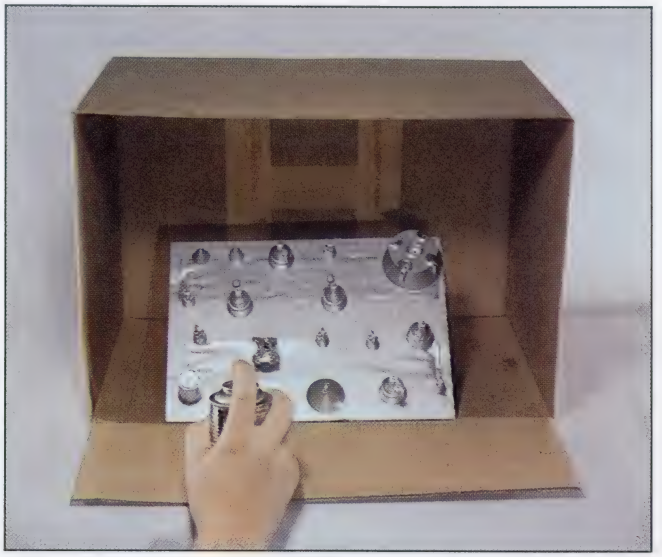
I did not spray an undercoat or primer for several reasons: I wanted to keep the painting steps as simple as possible; the yellow parts are so few and hidden as not to require special attention; and I wanted to avoid paint "build-up" on the small and contoured silver parts. Later, however, when I painted the large stages, I did use a flat white as the first coat.

One important step remained before painting: washing. I removed the parts from the cardboard mounting sheets and placed them in a pan (the sink will also do) of water with a few drops of mild detergent added. **I used an old toothbrush to gently scrub the parts, which removed finger**



oils as well as oils from the plastic molding process, thus making the paint adhere better.





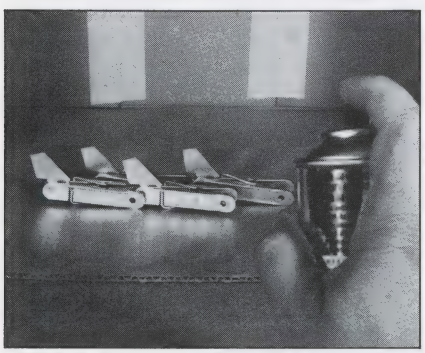
After washing the parts, handle them as little as possible. I rinsed them in clean water and placed them back on the cardboard sheets. This time I spread them out for painting, which meant I had to make up another sheet just to hold all of the silver-to-be parts.

I purchased five cans of aerosol paint for the project: yellow, silver, flat white, gloss white, and gloss black. I painted the yellow and silver parts at this time.

A large cardboard box served as my spray booth. I cut down the ends and top so they would not be in the way and placed the booth in an area where there was adequate ventilation.

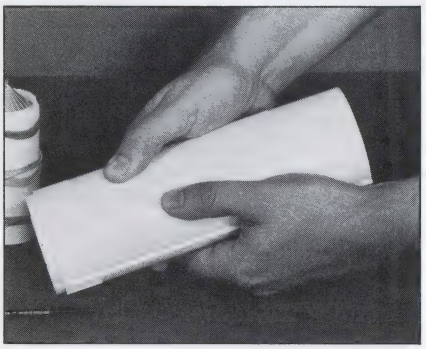
I began spraying to the left of the objects and made a deliberate pass to the right, staying 9-12 inches away, and released the button only after my hand passed completely to the right of the objects. Do not start spraying with the nozzle pointed at the object, and do not stop the motion or go too slowly while spraying: This will cause uneven coverage as well as pooling of the paint.

Because many of the silver parts were rounded, I painted them in several passes, rotating the cardboard between passes. Because it's easy for too much paint to build up and begin running when you do this, I stopped completely at the halfway point and waited a day for the paint to dry before continuing. **I was able, however, to paint both sides of the first-stage stability fins at one time by placing them in clothespin holders.**



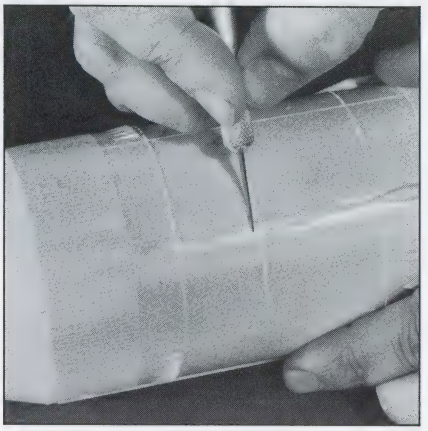
Before painting, I had placed the spray cans in a pan of warm water for several minutes to help the paint flow better. Now, after painting, I turned the aerosol cans upside down and pressed the nozzle until the paint cleared and only propellant came out. This prevented paint from clogging in the nozzle.

After the yellow and silver parts were dry, I was ready to assemble the stages and begin showing some progress! I cemented three cylinder domes and two rocket mounting structures in place in the halves of the major stages and then joined the other halves. **Although I had prefit the halves as best I could, I still found it helpful and important to flex the halves into perfect alignment as the liquid cement was drying.**

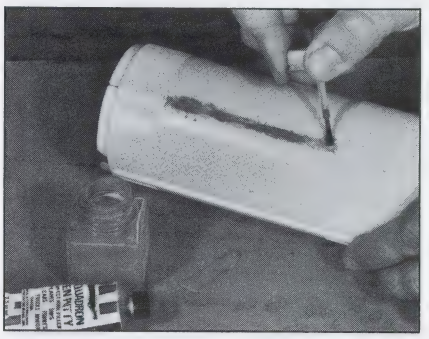


Once the cement appeared to hold the halves in place as I wanted, I placed rubber bands tightly around the stages for overnight drying. In fact, I even placed some of the rubber bands in position at one end of the stage while I was still applying cement at the other end of the stage.

After allowing the stages to dry at least overnight, I used the edge of my knife blade to scrape along the join lines. **I was careful with the second stage not to run my knife into any of the raised detail.** By and large, the seams looked smooth after adzing. But there were still a few gaps and uneven areas that could use putty.

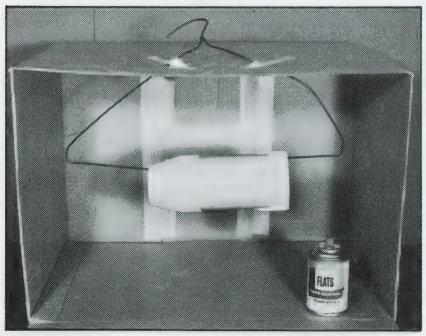


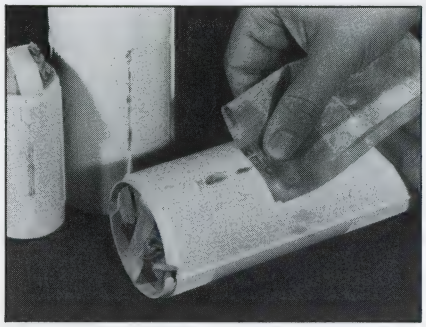
I repeated the process I had used with the Service Module: I applied thin coats of Green Putty cut with Testors liquid cement (I used the Testors bottle-cap brush as the applicator). I sanded with fine and then extra-fine Flex-I-Grit sanding film. After most of the seam was sanded smooth, I still had to repeat the application at a few points. Finally the seams were smoothed to the point where they hopefully would not be noticeable through a coat of paint.



I covered the yellow domes and silver cones with paper toweling (newspaper

also will do) and held it in place with masking tape. **Then, I mounted the stages in turn on a bent wire clotheshanger suspended from the top of my spraybooth. After a coat of flat white was applied, I**





inspected the puttied areas for imperfections. More putty and sanding were in order for several areas. The procedure of priming with flat white, puttying, and sanding was repeated until the seams were smooth. The other white parts were sprayed during this session.

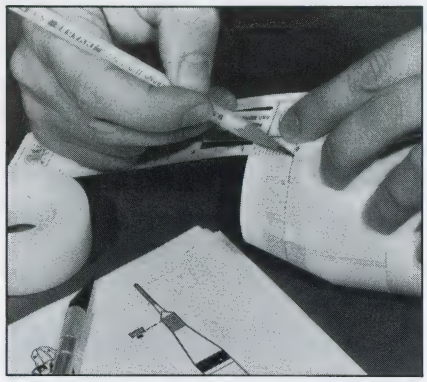
I used gloss white enamel for the final finish coat of paint. I had to apply a little more across the seam area to completely cover the darker appearance of the putty.

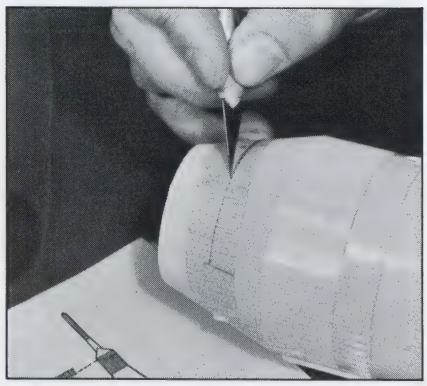
Once the final white coat had been sprayed on all the stages (as well as the Lunar Module "garage," escape tower, and interstage connecting ring between the first and second stage) and permitted to dry for several days, I began the most meticulous and error-prone part of the project: masking for the second exterior color, black.

I used a *sharp* new No. 11 blade on my X-acto knife, a straightedge, Scotch Magic Transparent Tape, and a piece of glass on which to cut the tape.

I placed a section of tape on the glass, cut a new edge with my knife and straightedge, and began placing the tape along the edge of the paint pattern shown in the instructions and on reference photos. I mounted all the stage assemblies (the twist-ring mounts permit you to assemble and disassemble the rocket for various states of display) through stage two and masked them at one time to make sure the vertical paint separation lines would be in alignment. Later, I cut the tape between stage one and two so that the stages could fit into my spray booth and make painting easier in general.

Masking the cone-shaped top of stage two required a little extra thought. Curved or angular pieces are more difficult to mask than flat pieces, and it soon became apparent it would be very difficult to curve the tape to match the horizontal separation line circling the cone about halfway up. So I placed a piece of tape directly over the separation line area. **With a small ruler, I measured one-half the distance from the top of the cone and made a tiny pencil mark on the tape. I moved the ruler**

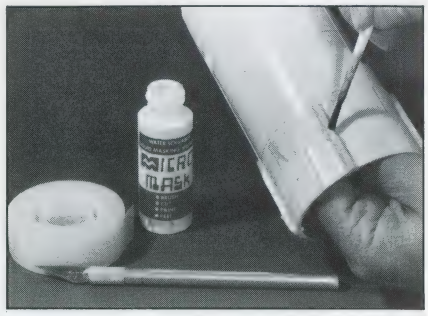




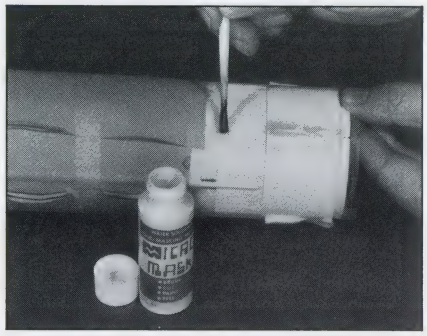
to the adjacent rib, measured, and made another mark. After I had completely marked the separation line, I made a sharp cut from pencil mark to pencil mark with my knife. I filled in with more tape below the separation line and also made vertical cuts along the rib lines to complete masking the pattern used on the Saturn V's. Tape newspaper or paper towels over large surfaces to protect against overspray.

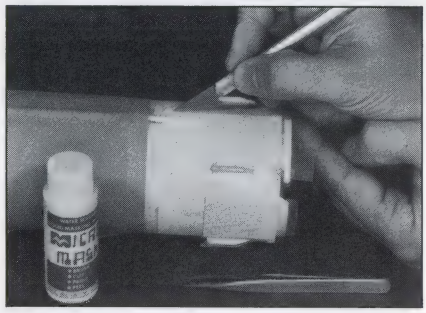
Ribbed surfaces are also difficult to mask because the tape tends to pull away from the many contours. Thus, paint overspray seeps under the tape and ruins the sharp separation line. Therefore, just before painting, I went over the surface and pressed my fingernail firmly against the tape along the separation lines and along each rib to make the tape adhere tightly.

In difficult masking situations, you can also try a masking fluid such as Micro Mask. **I brushed Micro Mask over several of the protruding vanes which would have been awkward and time-consuming to mask using tape.** Micro Mask dries (I allowed overnight drying time) to a rubber-like covering that effectively covers all



shapes of surfaces and can be peeled off after painting. It also can be cut with a hobby knife to form separation lines. **I brushed Micro Mask over some of the separation lines where the ribbed sur-**



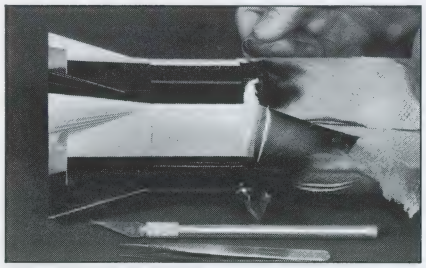


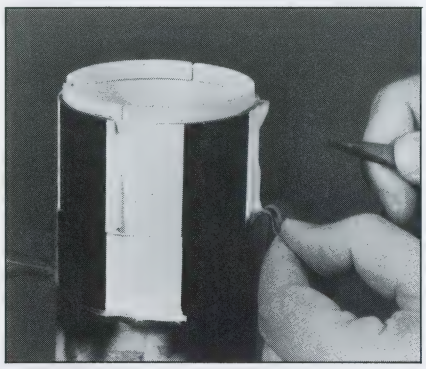
face met the flat surface and the tape was pulling away from the ribs. When dry, I sliced through the material along the separation line and peeled away the part on the area to be painted. The remaining Micro Mask had flowed under the tape and hardened, creating an effective separation line.

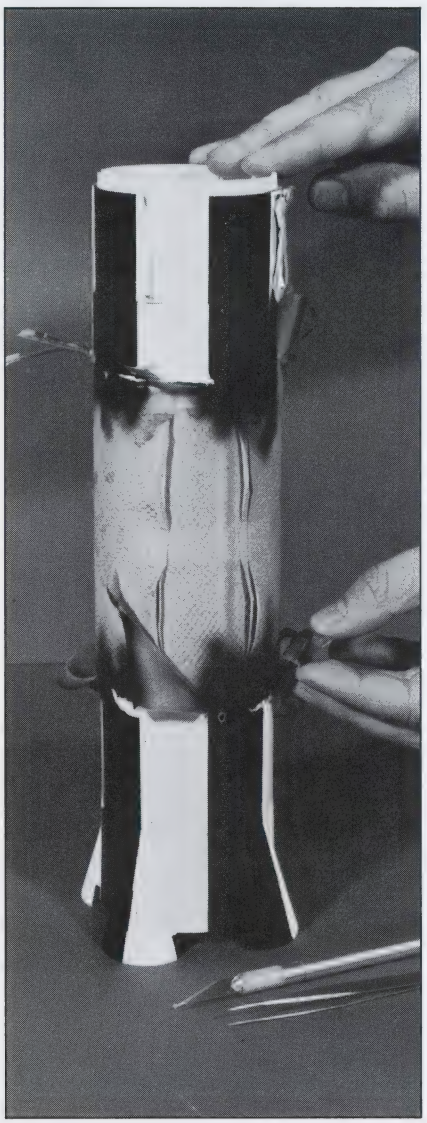
Masking fluids require a degree of expertise to use and may not always be for the beginner. If the covering doesn't come off easily, little globs of material may remain and mar the surface as you try to rub and scrape them off. Use a rubber cement pick-up, available at art-supply stores, to lift remaining material.

During painting, I still made sure to aim the spray directly at the masked separation line, never at an angle toward the masking line which would increase the chances of spray getting under the tape.

Remove the masking as soon as you have finished the painting. **I used my hobby knife to pick at the corner of the tape and then used a tweezers to pull the tape back at an extreme angle, almost**



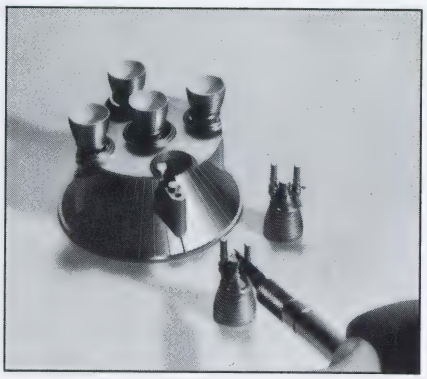




parallel to the surface of the model. Of course, you can use your fingers to peel off large pieces of tape, but remember to pull the tape slowly, evenly, and at an angle close to the surface.

In those places where some paint did seep behind the separation line, I used a small-tip brush to carefully touch up or my knife to carefully scrape away. I also masked off the bottom of the first-stage engine cowlings and sprayed them with silver.

At this point, I could have applied decals and a final clear coat to the exterior, but I was getting anxious to see all the parts assembled. Because I had painted most components before assembly, I still had to attach such items as the stabilizing fins and rocket motors. Plastic cement will not adhere to paint; therefore, I had to remove any paint from mating surfaces. **With my hobby knife, I scraped the edges of the**



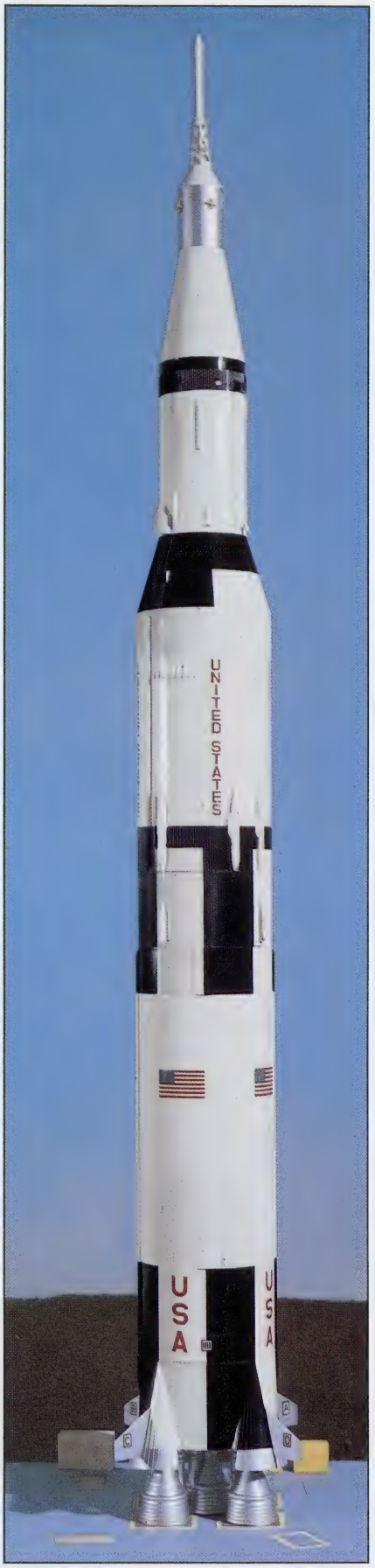
rocket motors and corresponding areas on the mounting structures. Assembly followed.

I brush-painted the tiny Service Module thrusters yellow while they were still on the sprue. The Apollo capsule's main heat shield was painted gray. Assembly followed.

The glossy paints I used provided a smooth finish for direct application of the decals, which I applied in the manner described in detail on page 71. After decaling, I mounted all the stages and gave the entire model a coat of Testors Glosscote.

At last I had a gleaming replica of the rocket that had launched men to the moon. The project had taken many days — far more than a moon mission itself. In fact, it had taken more days, one might question, than a so-called "beginner's project" should. But a beginner's project should not necessarily be a "fast" project.

To build any model so that it looks like a fine replica and not merely a toy will take time. Time to correctly apply cements and paints. Time to allow adhesives, putties, and paints to dry thoroughly. Time to carefully file, sand, and mask. To take the necessary time means a modeler has to develop patience. And patience is perhaps the hardest trait for the beginner to learn. Learn patience and skill in modeling will follow. If the beginner will exercise patience with the Saturn V, he or she will have a fine model on which to develop a broad range of modeling skills.



"One giant leap for mankind"...

APOLLO

JAMES E. OBERG

THE APOLLO SPACESHIPS opened the grandest frontier in the history of exploration, and they blazed the farthest and longest trails ever ridden by explorers. The quarter-million-mile voyage to the moon will doubtlessly someday be eclipsed by million-mile hops to the planets and nearby stars, but Apollo will always remain symbolic of the first visit by men to another world beyond the Earth. Project Apollo proved that humanity is no longer bound to its planet of birth.

Apollo spaceships also played an instrumental role in the triumphant triple expeditions to the space station Sky Lab in 1973-1974 that set space endurance records and unveiled space secrets. More space history was made a year later during the epochal Soviet-American space linkup between a Russian Soyuz spaceship and the last American Apollo spacecraft.

The lunar expeditions of 1969-1972 actually made use of two separate manned space vehicles, both included in the project named Apollo. No more unlikely set of space twins could be imagined — the conical, sleek Command Module and the awkward, misshapen two-staged four-legged Lunar Module. The Command Module (or CM) remained attached to the cylindrical Service Module (or SM) which provided the astronauts with power, air, and propulsion. The Lunar Module (or LM) made the actual moon landing while the Command and Service modules remained in lunar orbit many miles overhead.

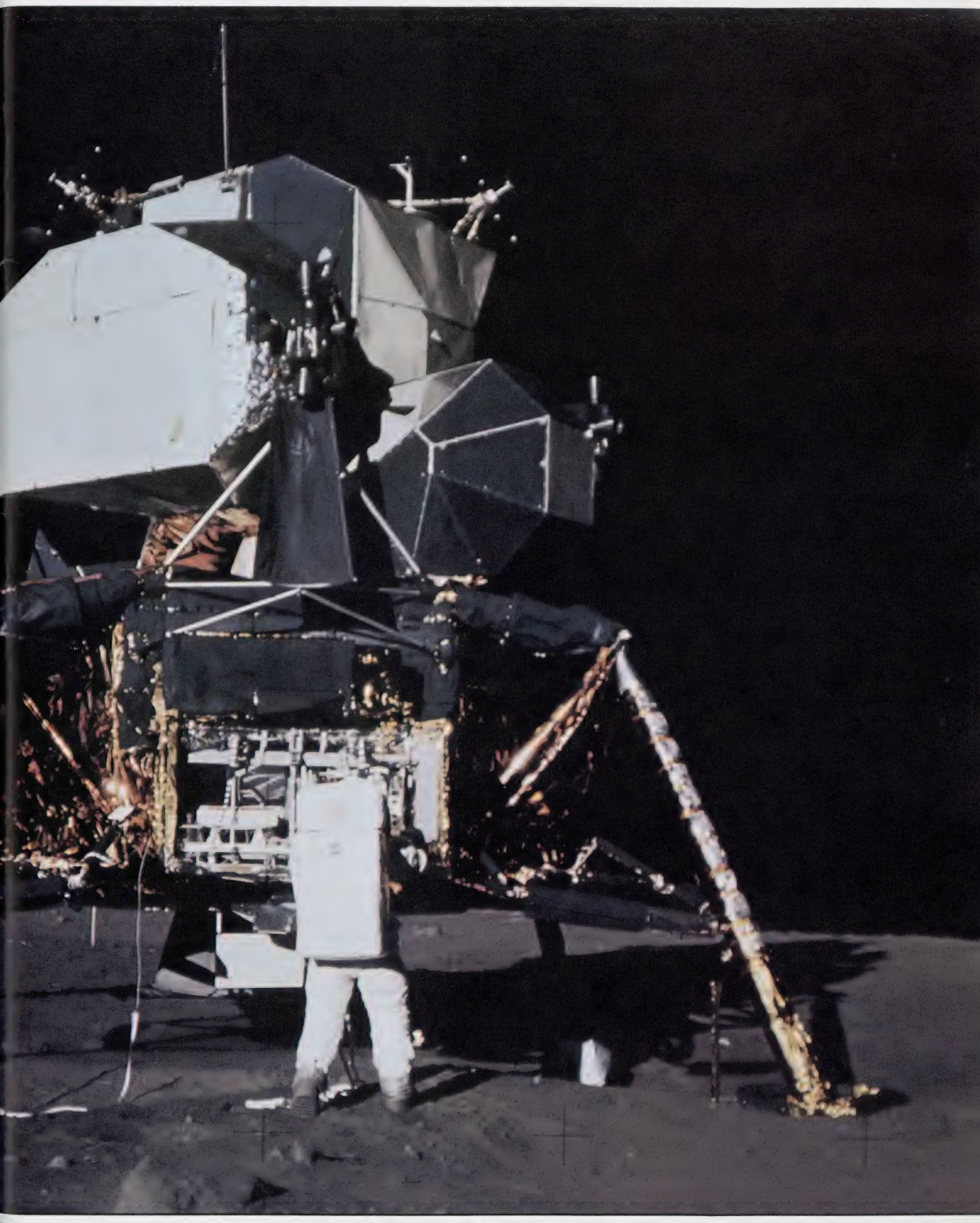
The Command Module was the section which ultimately returned to earth. During the mission, it provided living and working space for the three-man crew. The astronauts lay side by side on couches, with the main control panel stretched out above them. All the dials, switches, displays, buttons, and other gauges covered a main console 9 feet wide by 3 feet high.

The leftmost seat was occupied by the flight commander, the senior astronaut. The middle seat was for the Command Module pilot, whose duties involved guidance, navigation, and special Command Module functions. The right seat was for the Lunar Module pilot, who was also responsible for monitoring engineering systems on the Command Module (on flights without a Lunar Module, the man in this seat was a specialist in engineering or scientific experiments). The middle seat was removable in flight to provide more room.

The main entry hatch was positioned in the wall of the Command Module so that the center astronaut could reach over his head and unlatch it quickly. At the feet of the three crewmen was a "lower equipment bay" containing lockers and navigational sighting equipment.

Although the entire Apollo program drew heavily upon technology developed by the U.S. armed forces, NASA and the astronauts themselves emphasized the pacific and imaginative aspects of lunar exploration. Neil Armstrong's first words as he took man's first step on the moon were "That's one small step for a man; one giant leap for mankind." A plaque on the LM ladder read "Here men from the planet Earth first set foot upon the Moon, July 1969 A.D. We came in peace for all mankind."

NASA



Rendezvous and docking maneuvers are among the most difficult tasks of space flight. Computers handle the mathematical calculations, but rendezvousing pilots must carefully align the spacecraft during the docking. Apollo 9 gave NASA practice in docking the CSM and LM while in earth orbit. Here are the Apollo 9 LM and CSM as seen from one another.

From this section, a small tunnel ran up behind the control panel to the nose of the conical Command Module.

During moon flights, this tunnel led to the Lunar Module; on Skylab flights, it led to the space station itself; and on Apollo-Soyuz, it led to the docking module and thence to the Soviet spacecraft. The Command Module pilot was responsible for opening and closing the airlock hatches at the nose of the Command Module, and for handling the removable docking equipment (the probe and socket).

Aft of the Command Module was the Service Module, and these two units were so closely related that they were generally given an abbreviation of their own — CSM — or Command/Service Module. The Service Module provided all the power to the Command Module, via fuel cells. It contained the Spacecraft Propulsion System, or SPS, which allowed the astronauts to steer through space. Indeed, without the SPS, the astronauts would have been unable to come home. Most of the volume in the Service Module was taken up by fuel tanks for the rocket engines.

The Service Module was only jettisoned at the last moments of flight, when batteries in the Command Module could carry the electrical load for an hour more or so.

For the lunar landing flights, a third module was employed: the Lunar Module. It was the craft which made the landing, while the earth-return vehicle remained — for fuel efficiency — in orbit above the moon under control of the Command Module pilot.

Two astronauts stood in front of a control panel in the Lunar Module. There were no chairs or couches since the gentle accelerations in the weak lunar gravity field did not require them. Each astronaut had a window to look out and downward from, which would have been awkward from any other posture but standing. The main control panel was between them, although both walls and the ceiling were also covered with instruments and switches.

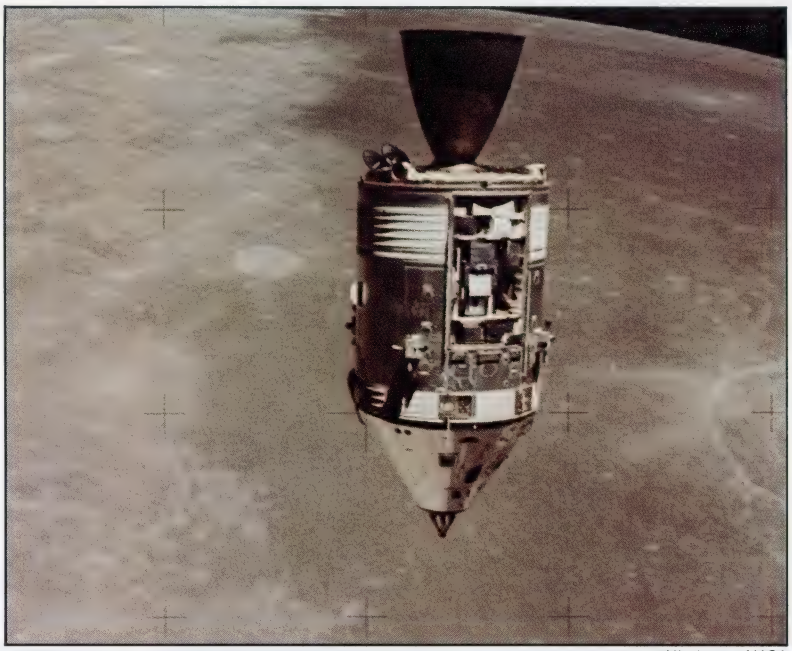
Below the central panel was the moonwalk hatch, located so that an astronaut with a life support backpack could crawl backwards through the door (which opened inwards) and onto a porch in front of the module. From the porch, a ladder led to the ground.

Most of the equipment for the activity on the lunar surface was located in lockers on the outside of the Lunar Module. The astronauts could remove this material once they were on the surface. On later flights, a folding moon jeep was included: The crew stood at a safe distance, pulled a lanyard, and watched their small four-wheeled "lunar rover" unfold itself from the side of their landing craft.

A commonly asked question involves how the astronauts got their heavy moon rock boxes and bags of film canisters back into the spaceship. They did not carry them up the ladder one-handed, but instead used what they called a "clothesline" pulley arrangement. One astronaut in the Lunar Module pulled on a line while the man on the surface attached the boxes to hooks on the line, which led from where he was standing up through the open hatch.

A second question is how the men on the moon slept. They did not stand up all the time, of course. For sleeping, they strung two hammocks: One ran from right to left across the cabin, and the other ran from front to back. Since the sun did not set on the moon, the astronauts had special shutters for their windows.

The Lunar Module consisted of two stages. Most of the fuel tanks, the descent engine, the landing legs, and the lunar surface equipment were all left behind when the astronauts left the moon in the "ascent stage." This was, so to speak, hardly more than a flying telephone booth.



All photos, NASA

Parting from the CSM was always exciting for the astronauts in the LM. Neil Armstrong and Edwin Aldrin left the Apollo 11 CSM pointing straight after them high above the desolate Sea of Fertility. David Scott and James Irwin enjoyed a side view of the Apollo 15 CSM (with the Scientific Instrument Module bay exposed) shortly before the lunar descent.

The rocket engine was under a cover right behind the crew, and the fuel tanks were strapped to either side of the cabin.

Much of the exterior of the LM was covered with protective Mylar foil. Various color patterns were seen on the different missions, with orange, silver, and yellow foil contrasting with surfaces painted in black and white. The colors reflected or absorbed the sun's heat differently, and a good choice of color scheme (combined with the appropriate orientation toward the sun) helped take the load off the spacecraft's cooling system. For example, on early lunar landings, the astronauts touched down soon after lunar sunrise at the landing site, when shadows were the longest (this facilitated the pilot's job of gauging the touchdown on unknown terrain). Later missions put down nearer to the lunar noon, which was excellent for orbital photographic reconnaissance but put higher loads on the LM's air conditioning.

MOON MISSION

Now let's take a look at a typical moon mission, and see how the components worked together.

At launch, the Command Module was in place at the top of the Saturn rocket. Only an escape tower extended above the CM. Had there been an emergency or aborted take-off, a solid-fuel rocket would have pulled the spacecraft up and away from the Saturn. In the entire history of the Apollo program, the escape system was never needed.

The Lunar Module was positioned below the Command and Service modules inside a "garage."

The Apollo and the third stage of the Saturn were placed into a low circular orbit of the earth, where additional navigational checks were conducted. Using the "parking orbit" technique also gave flight planners great flexibility in the event of a launch delay. After one or two orbits, the last stage of the Saturn was fired again to increase speed from 17,000 mph to 25,000 mph, sending Apollo to the moon.

The next order of business was to link up with the Lunar Module. The Command/Service Module was slowly flown off the LM "garage," causing the springloaded garage walls (SLA panels) to fly free. The Command Module pilot fired his thrusters to turn the spacecraft around. The exposed Lunar Module became the docking target, and the nose of the Command Module was piloted to attach to the roof of the LM. The connection secure, an order was sent to the LM tie-down latches to release the now-complete three-module spaceship.

The Saturn rocket's third stage and the walls of the LM garage drifted along in orbit. Ultimately the third stage was directed to hit the moon, providing known calibration impacts for lunar seismographs.

During the three-day coast up and out to the moon, the astronauts checked out the Lunar Module and made midcourse corrections as needed.

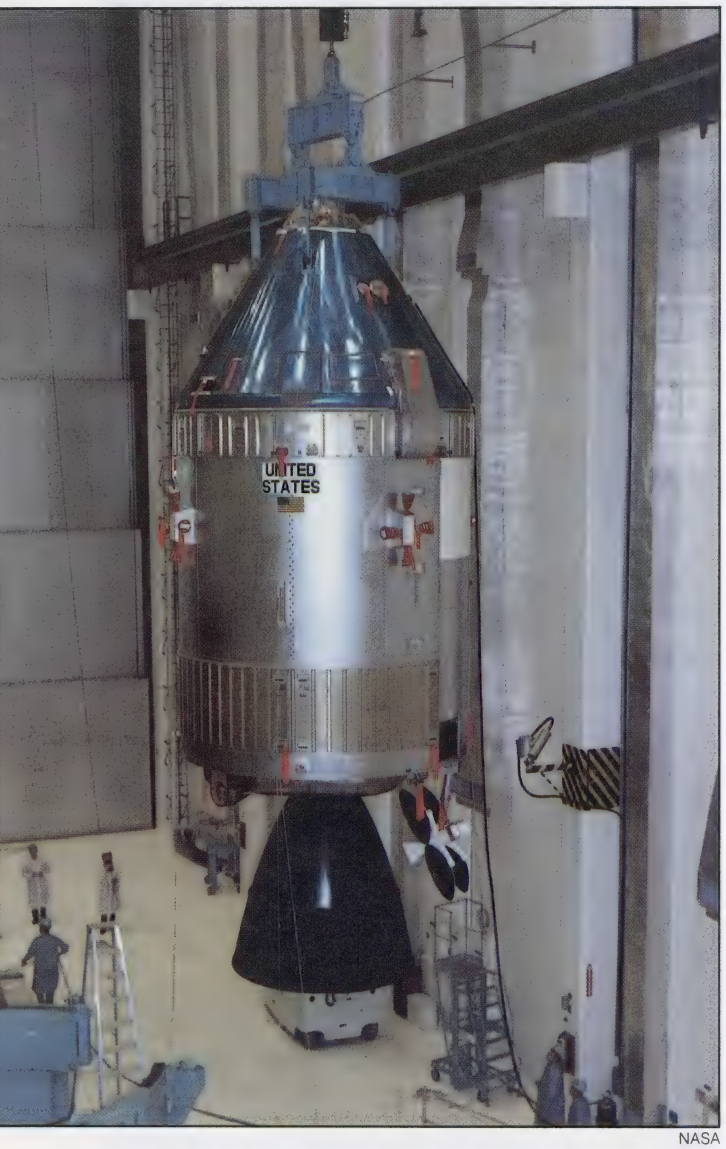
As the 50-ton spacecraft (most of the weight was fuel) whipped around the backside of the moon, on what would have been a giant "figure 8" orbit in space heading back toward earth, the astronauts fired their main rocket engine to slow down their speed. This allowed the weak lunar gravity to hold them back in an orbit circling the moon. After another day or two of navigational checks, two of the three astronauts separated the LM from the CMS (where one astronaut remained, ready if need be to return alone to earth).

The LM's descent engine was used to cut the orbital speed enough to permit the moon's gravity to pull the lander closer. Approaching the landing site at low altitude, the main descent engine continued to fire at a rate precisely calculated so that the lander's velocity reached

zero at the exact moment its altitude reached zero. Any leeway either way could have spelled disaster. If the astronauts had detected a bad guidance system, however, they could have hit the "abort" button, lighting the ascent engine and dropping the entire landing stage to its destruction while attempting themselves to get back into a stable lunar orbit where the Command/Service Module could recover them. Luckily, this failure never happened.

Aided by radars and by their computer, and using their own eyesight out the windows, the astronauts guided the LM to a final landing. Probes extending down from the landing legs alerted the crew to imminent contact, although in practice the astronauts ascertained this information from watching their spacecraft's shadow out the window.

Activities on the moon were two-fold: collect samples and implant instrument packages. On the early expeditions, the two astronauts went on foot; later they used the electric moon jeep which extended their range to tens of miles. Hundreds of pounds of carefully selected and documented samples were collected. At five sites, the nuclear-powered science stations called ALSEP (Apollo Lunar Science Experiment Package) were set up, with seismometers, magnetometers, ion detectors, and other instruments. These stations sent back coordinated readings for years, and were finally turned off in 1977 when their isotope power units began to run low.



NASA

Apollo 10 CSM was lifted for mating to Lunar Module Adapter at KSC's Manned Spacecraft Operations Building. Ablative heat shield (protected during shipment by blue coating) covered the CM; reflective material covered cone for flight.

The launch from the moon was one of the tensest moments of the missions, since there were no backup units and no chance of rescue. The design of the Lunar Module's ascent stage proved to be highly reliable, and all six lunar ascents were flawless. Hours after blasting off from the moon, the two moon walkers linked up in lunar orbit with the Command Module and transferred themselves and their precious film and samples. The LM itself would be detached and sent crashing to the moon's surface.

The orbiting CM had not been idle, either. From orbits of 180 to only 20 miles (depending on mission phase), batteries of high-resolution cameras surveyed the moon, while on later flights a laser altimeter measured the shape of the surface. Small sub-satellites were jettisoned to continue lunar studies.

Leaving circumlunar orbit was the next critical procedure, as the Command/Service Module's main engine had to perform flawlessly. It fired while the astronauts were behind the moon, flinging them up and out of the moon's gravity field to where the earth's gravity would drag them back. For the next three days the Apollo fell, picking up speed from a few thousand miles an hour to 25,000 mph right before atmospheric entry.

Before entry the faithful Service Module was cast off, exposing the heat shield at the base of the Command Module. The capsule decelerated and heat built up during the dramatic final moments of flight. All went well. The CM slowed to only a few hundred miles per hour, slow enough for its parachute to release for the final descent to an ocean splashdown, where recovery ships were waiting.

This summarizes the standard flight profile. Of course, things didn't always work out to the standard. Some things went wrong. Miscalculatons were made. Disasters happened, or were barely averted.

The worst Apollo disaster took place not in flight but in training. On January 27, 1967, Virgil I. Grissom, Edward H. White, and Roger B. Chaffee, the first Apollo crew, were killed during a ground test at Cape Canaveral. Fire broke out in the capsule, and the noxious fumes from the flames asphyxiated the astronauts.

Major changes were made in the Apollo Command Module, especially in regard to the fire danger of a pure oxygen atmosphere. The pure oxygen had been selected over a two-gas system using oxygen and nitrogen because it was simpler, lighter, and easier. It greatly facilitated space walks, making "pre-breathing" to clear the tissues of nitrogen unnecessary. But it heightened the danger of fire, and a series of miscalculations had killed three men.

The first change involved the use of a mixed atmosphere for all ground tests and for launch as well. As the capsule climbed into space — where fires in zero gravity were less likely and would be less disastrous — the air gradually was changed to a pure oxygen composition. Also, a quick-opening hatch — which would have saved

the Apollo 1 crewmen — was added. Materials to be used inside the capsule underwent rigorous fire tests.

Another major disaster almost occurred after an oxygen tank in the Service Module exploded when Apollo 13 was halfway to the moon. The landing was cancelled, and for two tense days even the lives of the crewmen were in doubt. All power in the Command/Service Module was crippled, so the astronauts had to live in the Lunar Module and use *its* engines to change course and return to earth.

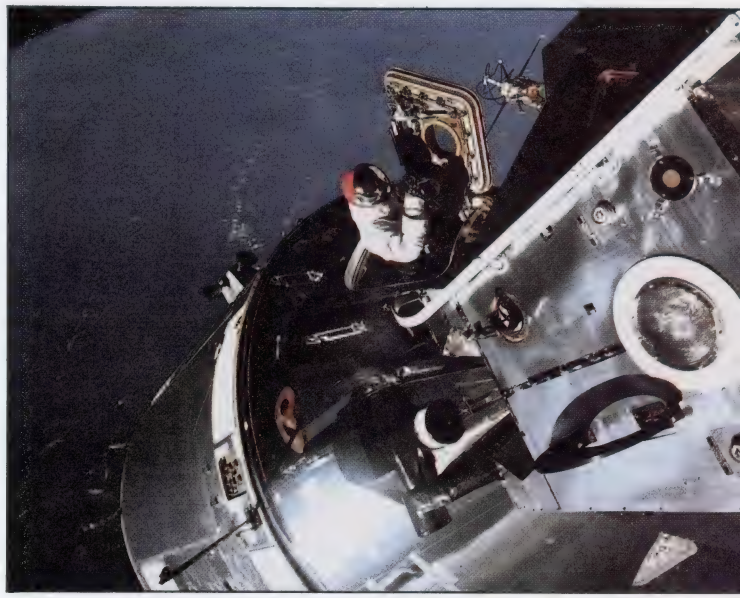
If such an explosion had taken place during the Apollo 8 moon flight (when no Lunar Module was attached), or on any lunar landing mission during its *return* to earth from the moon (when the Lunar Module had already been jettisoned), the astronauts would have perished. The accident was traced to a test procedure at the launch site, which included a voltage application to heaters in the liquid oxygen tank. The power levels for the heaters had been decreased between Apollo 12 and Apollo 13, but one test group never got the word, and used the *old* current levels, overloading the heating element and burning off its insulation. In flight, the bare wire glowed white hot inside the tank, setting off an explosion as soon as it was turned on.

Safety considerations were high during Skylab, when the Apollo Command/Service modules had to remain docked to the space station for up to three months. A rescue Apollo was also available, to be flown by a two-man astronaut crew. Food lockers behind the crew couches were removed so that two additional seats could be installed, allowing a two-man Apollo team to launch, dock with Skylab, and pick up the three men in orbit. All five would return to earth inside the single Apollo. A similar design was possible during the Apollo-Soyuz linkup in the event that the two Russian cosmonauts had to return to earth along with the three Americans.

Once, the rescue ship was almost launched, when leaking fuel from the second Apollo visit to Skylab in August 1973 seemed to indicate that the spacecraft had become disabled. Ground controllers determined that it was still safe to fly. But a rescue ship would not have helped the third and last crew when, during the return to earth, the retro-rocket control system failed, stranding the astronauts in orbit (as in the prophetic movie *Marooned*). Luckily, an alternate procedure on the next orbit allowed the men to come home safely; there never would have been time to launch the rescue ship before the marooned Skylab astronauts suffocated.

The various modules of the Apollo spacecraft were built and tested all over the United States. From Los Angeles came the Command and Service modules, built by North American Rockwell. From Long Island came the Lunar Module, built by Grumman Aerospace Corporation. The separate sections were transported by air, inside a special airplane with an enlarged cargo hold nicknamed the "Pregnant Guppy."

The design of a manned moonship had occupied the imaginations of space-minded engineers for decades before Apollo was born as the child of the Cold War competition between the U.S.A. and U.S.S.R. that fostered the so-called "space race." Years before Pres. John F. Kennedy committed America to the moon landing "within this decade" (he made the speech in May 1961, a month after the Russians put the first man into space), space theorists in Russia and England had dreamed of a squat, unstreamlined "moon bug" which would land the first men on the moon. When the Apollo 11 crew landed on July 20, 1969, it was in a spaceship which bore an uncanny resemblance to designs published by the British Interplanetary Society — in 1939! And the technique of sending a scout ship down to the moon from an orbiting mother ship had been proposed a generation before by a Russian mathematician, but the idea was forgotten in his own country and had to be reinvented in the United States.



NASA

A scheduled two-hour spacewalk by Russell Schweickart during Apollo 9 was canceled after he suffered nausea and vomiting, but he was able to test the Extravehicular Activity suit under space conditions from the open CM hatch.

Most science fiction scenarios of moon flights had foreseen a winged spaceship blasting off from earth, touching down on the moon, and then returning directly to earth. When space engineers, responding to President Kennedy's rallying cry, actually plotted the fuel requirements and rocket power needed, they ran into major problems.

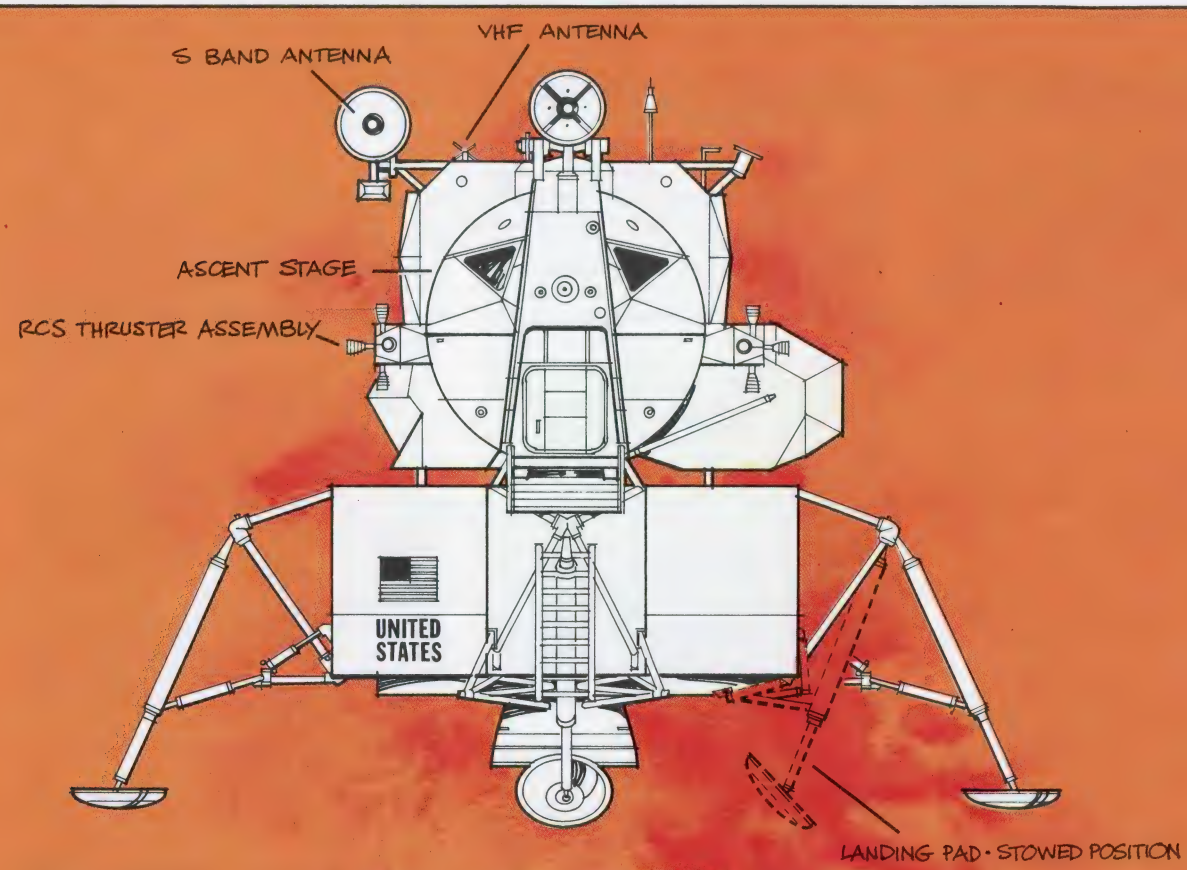
The moonbound rocket was much too heavy. Either it would have to be assembled from hardware launched separately into earth orbit, or a giant rocket twice the size of the still-imaginary Saturn V would be needed. The fuel cost of taking all of the main equipment and earth-landing hardware down to the moon's surface and back into space was simply prohibitive.

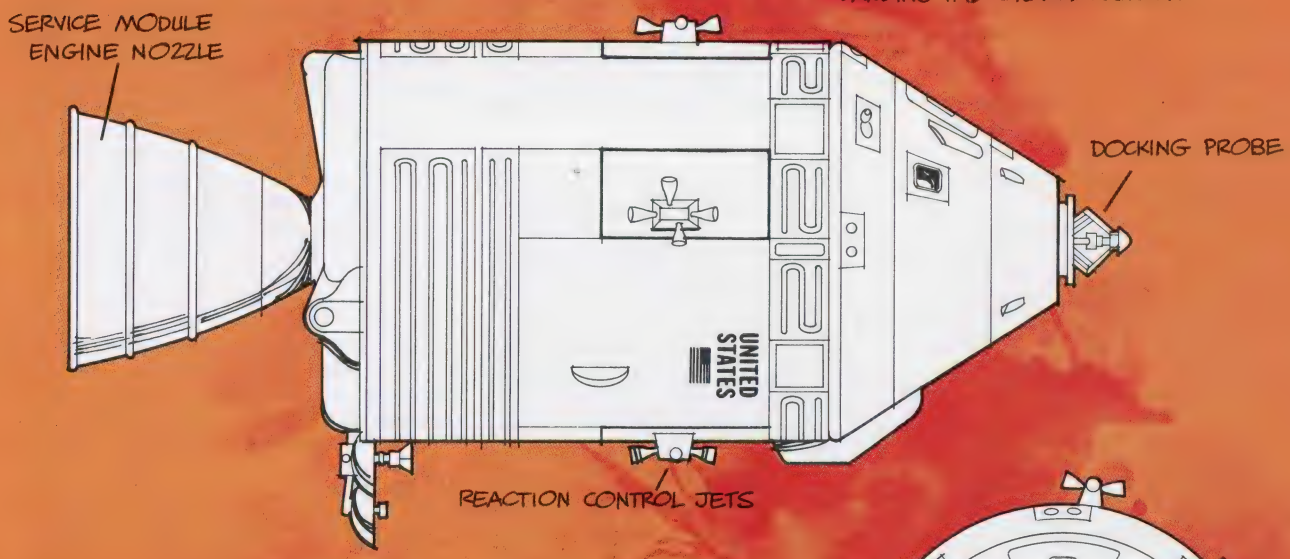
A young NASA engineer, John Houbolt, found the shortcut, unknowlingly duplicating the logic of the forgotten Russian, Yuri Kondryatuk. The main spaceship could circle the moon at a safe altitude while a scout ship made the actual landing. The total weight of such a spaceship combination would only be half as much as the direct-landing-and-return system.

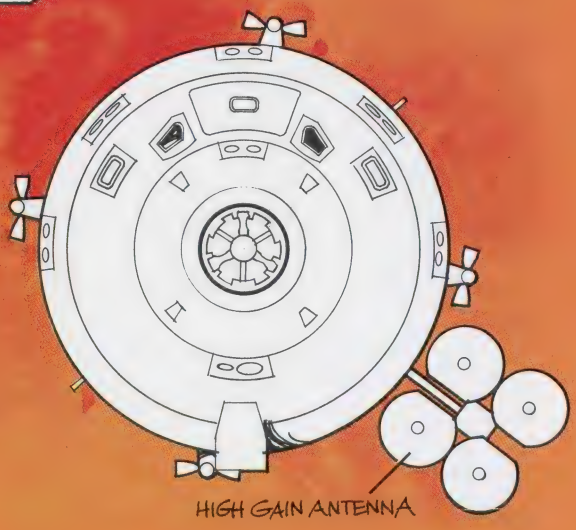
Houbolt's plan met strong resistance, since it required the development of an entirely new space vehicle, and it required the linkup of the moon landing vehicle with the mother ship on the way back to earth. These feats were untried, and might prove impossible. But when former critic Dr. Wernher von Braun studied Houbolt's idea and decided he had been wrong in opposing it, the American space team adopted it enthusiastically.

MISSION CHRONOLOGY, Apollo/Saturn

Mission number	Dates	Duration	Earth orbits	Moon orbits	Crew-members	Capsule, Module names, serials	Booster serial, Mission description
Apollo 4	Nov 9, 1967	8 hrs 37 min	3	—	unmanned	CM 017	Saturn 501 Engine tests, first flight test of the Saturn V
Apollo 5	Jan 22, 1968	7 hrs 50 min	5	—	unmanned	LM 1	Saturn SA-204 Test Lunar Module and Lunar Module propulsion systems in earth orbit
Apollo 6	Apr 4, 1968	9 hrs 56 min	3	—	unmanned	CM 020	Saturn 502 Second test of the Saturn V launch vehicle
Apollo 7	Oct 11 to 22, 1968	260 hrs 9 min 3 sec	163	—	Schirra Eisele Cunningham	CM 101	Saturn SA-205 Docking exercises, safety and reliability tests of Command Module systems
Apollo 8	Dec 21 to 27, 1968	147 hrs 0 min 42 sec	1.5	10	Borman Lovell Anders	CM 103	Saturn 503 Lunar orbital flight first manned Saturn V
Apollo 9	Mar 3 to 13, 1969	241 hrs 0 min 54 sec	151	—	McDivitt Scott Schweickart	CM 104 Gumdrop LM 3 Spider	Saturn 504 Test Command Module and Lunar Module in earth orbit
Apollo 10	May 18 to 26, 1969	192 hrs 3 min 23 sec	1.5	31	Stafford Young Cernan	CM 106 Charlie Brown LM 4 Snoopy	Saturn 505 Lunar orbit, examine landing sites from altitude of 50,000 feet
Apollo 11	Jul 16 to 24, 1969	195 hrs 18 min 35 sec	1.5	30	Armstrong Collins Aldrin	CM 107 Columbia LM 5 Eagle	Saturn 506 Lunar landing experiments, soil samples, deployment of EASEP package
Apollo 12	Nov 14 to 24, 1969	244 hrs 36 min 25 sec	1.5	45	Conrad Gordon Bean	CM 108 Yankee Clipper LM 6 Intrepid	Saturn 507 Landing at site of Surveyor 3, exploration of Ocean of Storms, deployment of ALSEP package
Apollo 13	Apr 11 to 17, 1970	142 hrs 54 min 41 sec	1.5	—	Lovell Swigert Haise	CM 109 Odyssey LM 7 Aquarius	Saturn 508 Explore Fra Mauro crater. "Houston, we've had a problem here." Mission aborted due to ruptured SM oxygen tank.
Apollo 14	Jan 31 to Feb 9, 1971	216 hrs 1 min 57 sec	1.5	34	Shepard Roosa Mitchell	CM 110 Kitty Hawk LM 8 Antares	Saturn 509 Explore Fra Mauro crater
Apollo 15	Jul 26 to Aug 7, 1971	295 hrs 11 min 53 sec	1.5	74	Scott Worden Irwin	CM 112 Endeavor LM 10 Falcon	Saturn 510 Explore Sea of Rains deploy lunar sub-satellite from lunar orbit. First Lunar Rover
Apollo 16	Apr 16 to 27, 1972	265 hrs 51 min 5 sec	1.5	64	Young Mattingly Duke	CM 113 Casper LM 11 Orion	Saturn 511 Explore Descartes region
Apollo 17	Dec 7 to 17, 1972	301 hrs 51 min 59 sec	2	75	Cernan Evans Schmitt	CM 114 America LM 12 Challenger	Saturn 512 Explore Taurus-Littrow area. Only Saturn V night launch
Skylab 1	May 14, 1973		—	—	unmanned	Saturn S-IVB shell, converted to manned workshop	Saturn 513, 2-stage configuration Orbiting space workshop for scientific experimentation. Orbital altitude 271 nautical miles
Skylab 2	May 25 to Jun 22, 1973 (28 days)	672 hrs 49 min 49 sec	404	—	Conrad Weitz Kerwin	CM 116	Saturn SA-206 First Skylab occupancy
Skylab 3	Jul 28 to Sep 25, 1973 (59.5 days)	1427 hrs 9 min 4 sec	858	—	Bean Lousma Garriott	CM 117	Saturn SA-207 Second Skylab crew
Skylab 4	Nov 10, 1973 to Feb 8, 1974 (84 days)	2017 hrs 16 min 30 sec	1214	—	Carr Pogue Gibson	CM 118	Saturn SA-208 Third Skylab crew
Apollo — Soyuz Test Project (Apollo 18)	Jul 15 to 24, 1975	217 hrs 30 min	138	—	Stafford Brand Slayton Leonov	CM 111 DM 2 (Docking Module)	Saturn SA-210 International co-operation in space. Craft remained docked for two days.



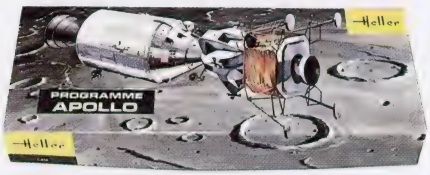




APOLLO SPACECRAFT AND LUNAR MODULE SPECIFICATIONS

Apollo Spacecraft: Command Module (CM)	
Height	10′-7″
Maximum diameter	12′-10″
Weight (at launch)	12,800 pounds
Habitable volume	210 cubic feet
Apollo Spacecraft: Service Module (SM)	
Height	22′-7″
Maximum diameter	12′-10″
Weight (at launch)	54,200 pounds
Lunar Module (LM)	
Height	23′-1″
Maximum diameter (over extended landing gear)	31′
Weight (at launch)	36,200 pounds
Habitable volume	160 cubic feet

Build Apollo by subassembly



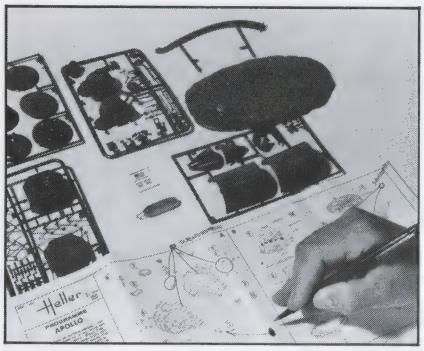
KIT: Programme Apollo
MANUFACTURER: Heller, France, Kit No. L 210
SCALE: 1/100
DIMENSIONS: Command and Service Module — $1^{11}/_{16}$″ diameter, $4^{1}/_{4}$″ long; Lunar Module — $2^{3}/_{4}$″ square over landing gear, $2^{3}/_{4}$″ high; Display base — 4″ x 7″ x 6″ high.

Bob Hayden

THE BASIC FORMS of the Heller Apollo kit are accurate and well detailed. With some minor reworking, proper painting, and a revised, subassembly-oriented construction sequence you can turn out an eye-catching miniature replica of the vehicles used in man's most daring extraterrestrial adventure.

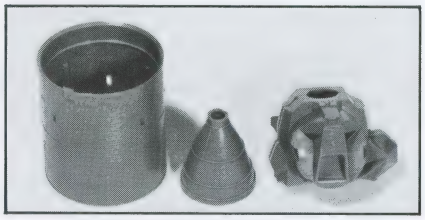
To start, research correct colors and patterns. You'll find the patterns on the craft differed significantly from mission to mission, so you'll have to choose one scheme and stick with it. I found the best source for this kind of information was my public library, in books on space exploration, in *National Geographic* magazine, and in an encyclopedia. While you research, decide whether your model will be finished "new" or "used"; this will make a difference in assembly.

Size up the kit. Study the instructions and look over the parts before you detach them from their runners. The instructions are in French, with English and German translations on the back of the sheet. **Write your own notes on the instruction sheet**



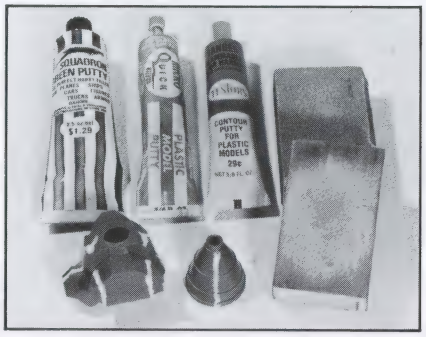
as you examine and develop an understanding of the model. Even if you don't intend to follow the sequence presented in the instructions, talk yourself through it, finding each part as it is called for, and noting how and where it fits.

The sequence of painting is the controlling factor in this construction project. My plan of attack was to assemble the major body portions of the model as subassemblies, do any sanding, filing, adzing, and joint filling required, and then prime and spray-paint these subassemblies and the remaining parts. The Heller kit is ideal for a subassembly approach, because it is divided into four portions as part of its design: Command Module, Service Module, Lunar Module ascent stage, and Lunar Module descent stage. **I began by making the following subassemblies: Lunar Module cabin with rear RCS thruster**



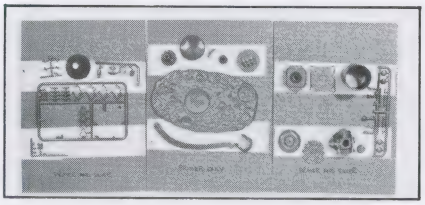
mounts (parts 1,2,4 and 5), Service Module body (6 and 7), and Service Module engine nozzle (10 and 11).

Little filler putty work is required on the Service Module body halves or engine nozzle, but the Lunar Module cabin halves fit together with unacceptable mismatches. **Fill these with putty, and sand with fine- and extra-fine sandpaper. Inspect your work, and repeat the filling**



and sanding process until you bring the surfaces to the proper contour and finish.

Separate all but the smallest parts from the runners and use a sharp modeling knife, sanding block, and files to clean up the mold parting lines and sprue attachment points. Wash the parts, including the subassemblies, in detergent, rinse well with clear water, and let them air-dry. **For priming, arrange the cleaned parts on sticky-side-up masking tape stapled to scrap cardboard.** Handle the cleaned parts with tweezers or disposable plastic gloves to prevent contaminating them with finger oils.



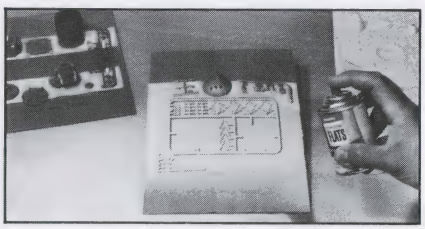
Simulating metal finishes effectively is important in any kind of aircraft modeling, and particularly so in space modeling, where many parts on the prototypes are left unpainted as a means of reducing vehicle weight. Before painting or priming the Apollo parts, you'll have to decide how to simulate the polished alloy surfaces of the CM, SM, and LM.

There are several ways to represent shiny metal surfaces; each method has its own advantages and drawbacks. Most common is the use of metallic paint, either enamel or lacquer, that carries millions of tiny metal particles in a standard paint vehicle. Gloss metallics give the better simulation of the shiny surface of the real thing, but hide detail. Flat metallics show up detail well, but lack snap and luster. I chose a semigloss lacquer for my model — a compromise. Whatever type of finish you choose, it is almost mandatory that you apply metallic paint by spraying in order to achieve a smooth, uniform, metal-looking surface. If you use an airbrush and can vary the air pressure, remember that metallic pigments — actually bits of metal — are heavier than regular colors, and require increased air pressure (on the order of 25-30 pounds) for proper application.

Another way to simulate metal is application of thin metal foil. Applied with an adhesive, the foil burnishes down over panel and rivet detail to form a very effective "skin." The complex, blocky shapes of the LM and the cone form of the CM preclude foil covering for our small-scale model, but foil covering is worth considering for larger-scale efforts.

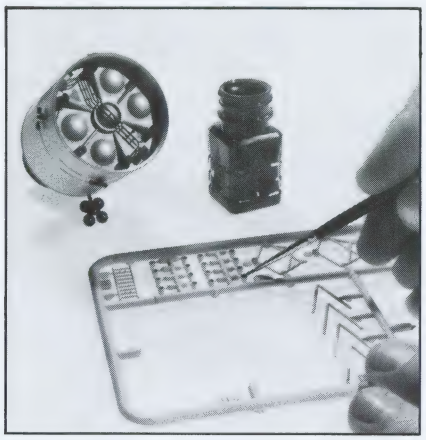
Rub 'n Buff is a wax emulsion that holds metallic particles in suspension. A paste, it is spread over the model and buffed to a deep luster with a soft cloth. It "shines up" in proportion to the smoothness of the surface it is applied over, and you must plan on applying either flat or gloss undercoat before applying Rub 'n Buff. The metal simulation is convincing — the disadvantages are time-consuming application and a tendency for the finish to tarnish as the model ages.

Whatever you choose for metallic finish, you'll need to prime or undercoat the parts. **You can apply enamel or other plastic-compatible primers with a brush, but the best method is to spray.** Use flat



white or light gray primer to show up imperfections, and sand the trouble spots before final painting. Lacking a standard primer, use flat white or gray paint in the same role.

After checking for parts that must be filled or resanded, respray the parts that will represent metal with your choice of metallic finish. Let this coat cure for at least two days. **Next, carefully paint cast-in details and small parts with a No. 00 spotting brush.** You'll find the masking-

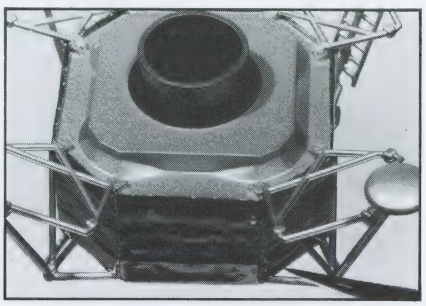


tape flats are convenient "handles" for the larger pieces, as are the sections of runner we left attached to the smaller parts. Handle the parts as little as possible from the time you clean them for painting until they are added to the model.

The most striking feature of the LM descent stage is the copper-orange Mylar covering. No material is furnished for this covering in the Heller kit, but I felt it is such a characteristic part of the prototype that it had to be simulated. I used copper-colored, lacquered, paper-backed aluminum foil wrapping. This is similar to gift-wrap foil, and can be found at art, craft, and stationery stores. Cut a 9" strip of the foil, $1\frac{5}{16}$" wide, and draw a pencil line $\frac{5}{16}$" from each edge. Hold a thin straightedge along each pencil line and bend the foil against it and back upon itself. This will give you a strip of foil $\frac{11}{16}$" wide, and the folds ensure that the white backing paper will not show at the foil edges.

Next, gently wrinkle the foil strip. Don't get carried away here; we want our "Mylar" to look creased, not battered! **Flatten the foil and apply water-soluble contact adhesive such as Micro Scale Metal Foil Adhesive or Elmer's Acrylic Latex Con-**

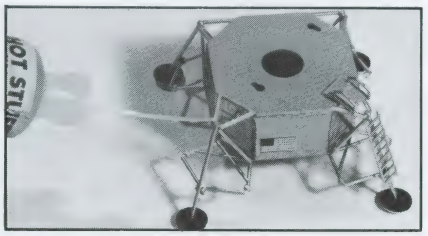
tact Cement to the back of the strip and the sides of the descent stage body. Let this coat dry for about 40 minutes and apply a second coat. When this is clear, carefully align the foil strip on the body and press it into place, one side at a time. Overlap the strip at the end, and plan ahead so the overlap comes at the rear of your model rather than beside the LM "front door" ladder as it did on mine! **When you assemble the descent stage,**



distort the foil slightly at the four corners to clear the upper and lower landing gear support arms.

I used liquid plastic cement for most of final assembly, but substituted ACC ("super glue") for joints between pre-painted parts where neatness was the most important consideration. **ACC is especially helpful in assembling the landing-gear legs. It is ultra-fast-setting, and very strong, even where there is little surface area in a joint.**

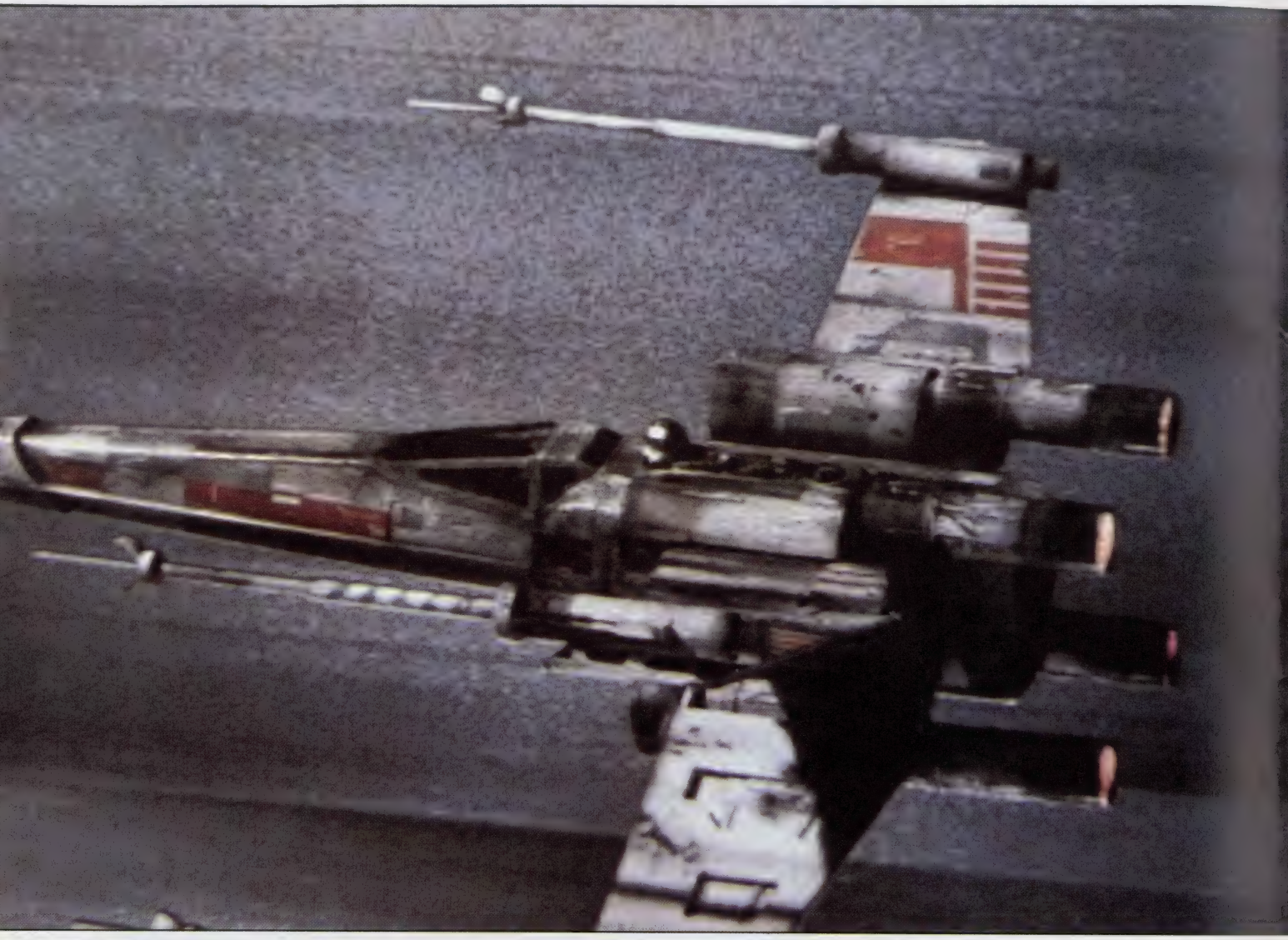
Finishing touches bring any model to

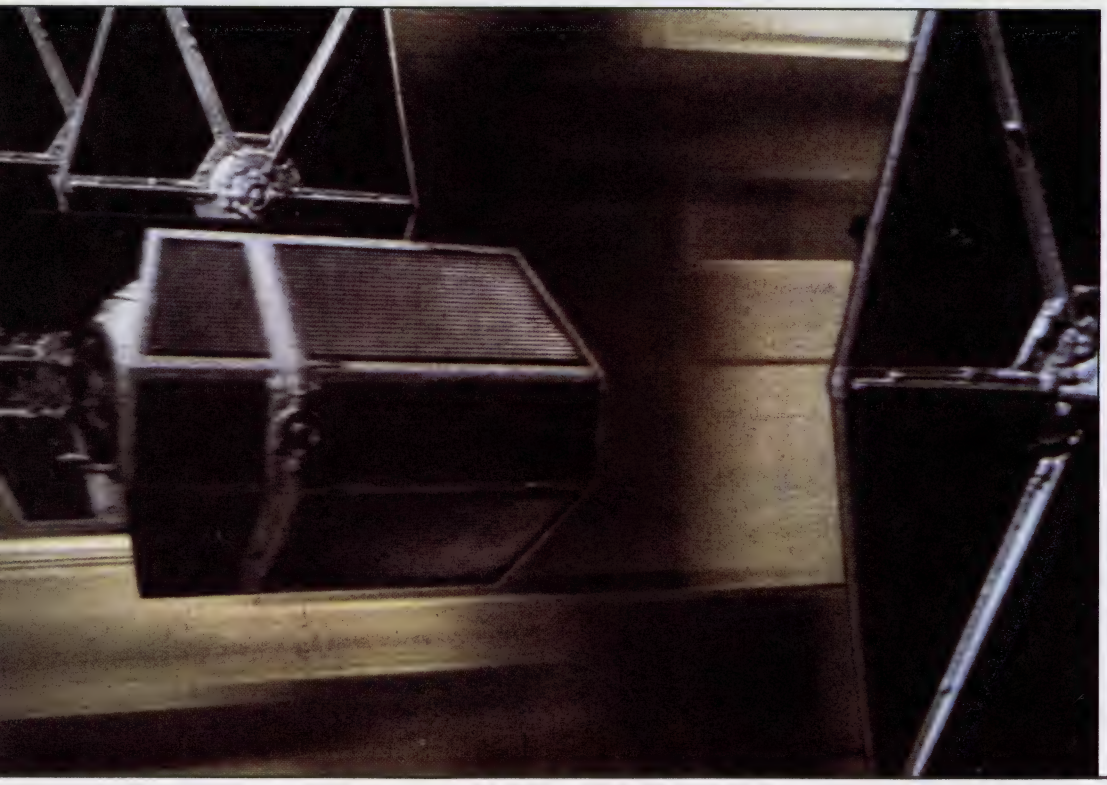


life; here are the extra things I added to complete the Heller Apollo kit. First, I finished the moon landscape base with dead-flat gray and gray-brown colors. The flat paint is a pleasing contrast to the semigloss metallic silver and shiny copper foil areas on the spacecraft. Next, I made a flag similar to those planted by the Apollo astronauts by applying flag decals from a model railroad "Bicentennial" locomotive decal set to thin styrene sheet. I used ACC to cement the flag to a length of stiff brass wire and to hold the wire into a hole drilled in the base.

I did not weather my model, although it has good possibilities for a weathering job. The heat shield on the CM can be painted to show the scorching that takes place during re-entry, and the LM landing gear foot pads can be dusted with gray moon dust made by powdering gray and tan pastel chalk sticks.

The final extra detail I added was an astronaut figure. This came from an out-of-production Revell 1/96-scale Apollo kit, and I consider it important to the overall display because it lends an easily understood scale element.

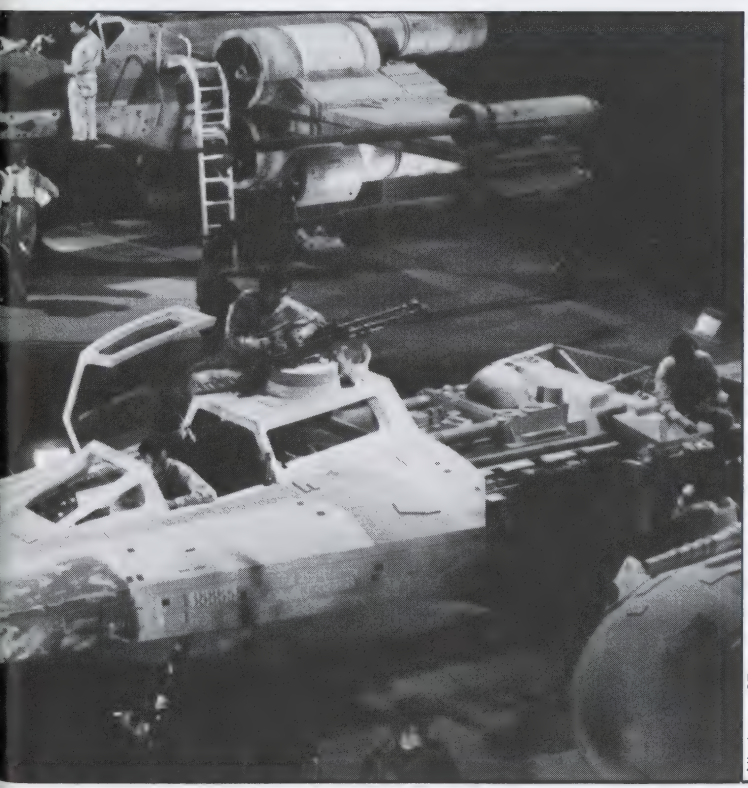




The Ships of Star Wars, especially...

X-WING FIGHTER AND DARTH VADER'S TIE FIGHTER

CHRIS TIETZ/GEORGE ELRICK



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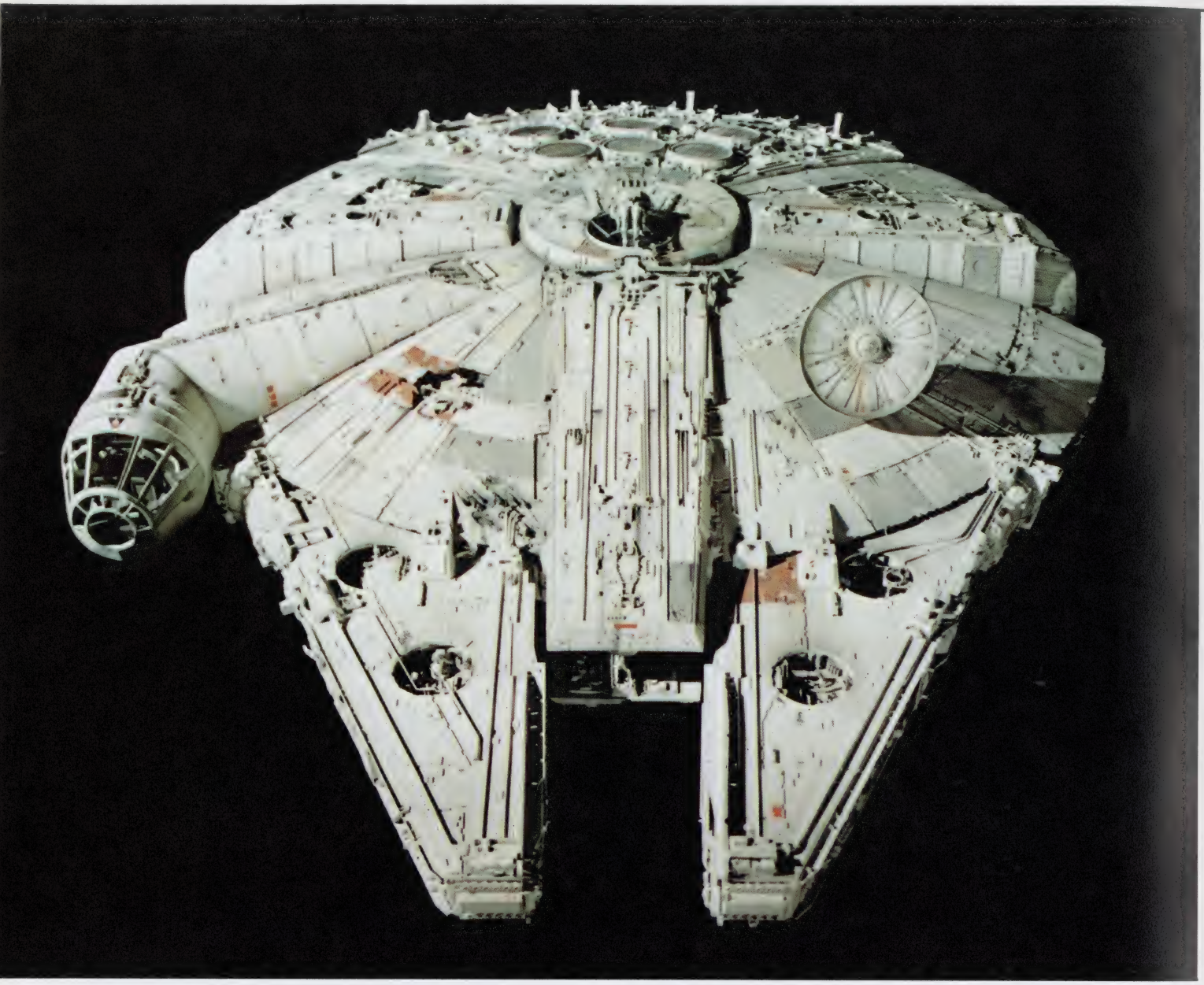
IN 1977 *Star Wars* detonated in terrestrial movie houses with the impact of an exploding supernova, increasing science fiction fandom a hundred-fold. Its overwhelming appeal has been attributed to several self-evident facts: (1) It creates a dazzling new mythology; (2) It simplifies life, depicting an extreme "us versus them" polarization of good combatting evil; (3) It parades seemingly endless special effects before audiences who have hungered for them since Stanley Kubrick's *2001: A Space Odyssey;* and, (4) It introduces seven interstellar vehicles the likes of which have never been seen on the screen: *realistic* spaceships, some of which impart a nitty-gritty aura of having been drop-kicked around a football field.

The story itself is fairly simple: "A long time ago, in a galaxy far, far away," a bunch of good guys heroically tangles with a bunch of bad guys. The bad guys are Imperials of the evil "Empire," which has spread, Hitler-like, from planet to planet and from solar system to solar system. The good guys are the rebels: a tattered Alliance which aims to restore the honor and integrity of the Old Republic, even if this entails perishing in electronic shoot-outs that make The Gunfight at OK Corral seem

(Facing page) Luke and faithful R2D2 are speeding through the Death Star trench, but Darth Vader, in TIE fighter has them in his sights. (Left) Full-scale Y-wing and X-wing rebel fighters are serviced before the battle.



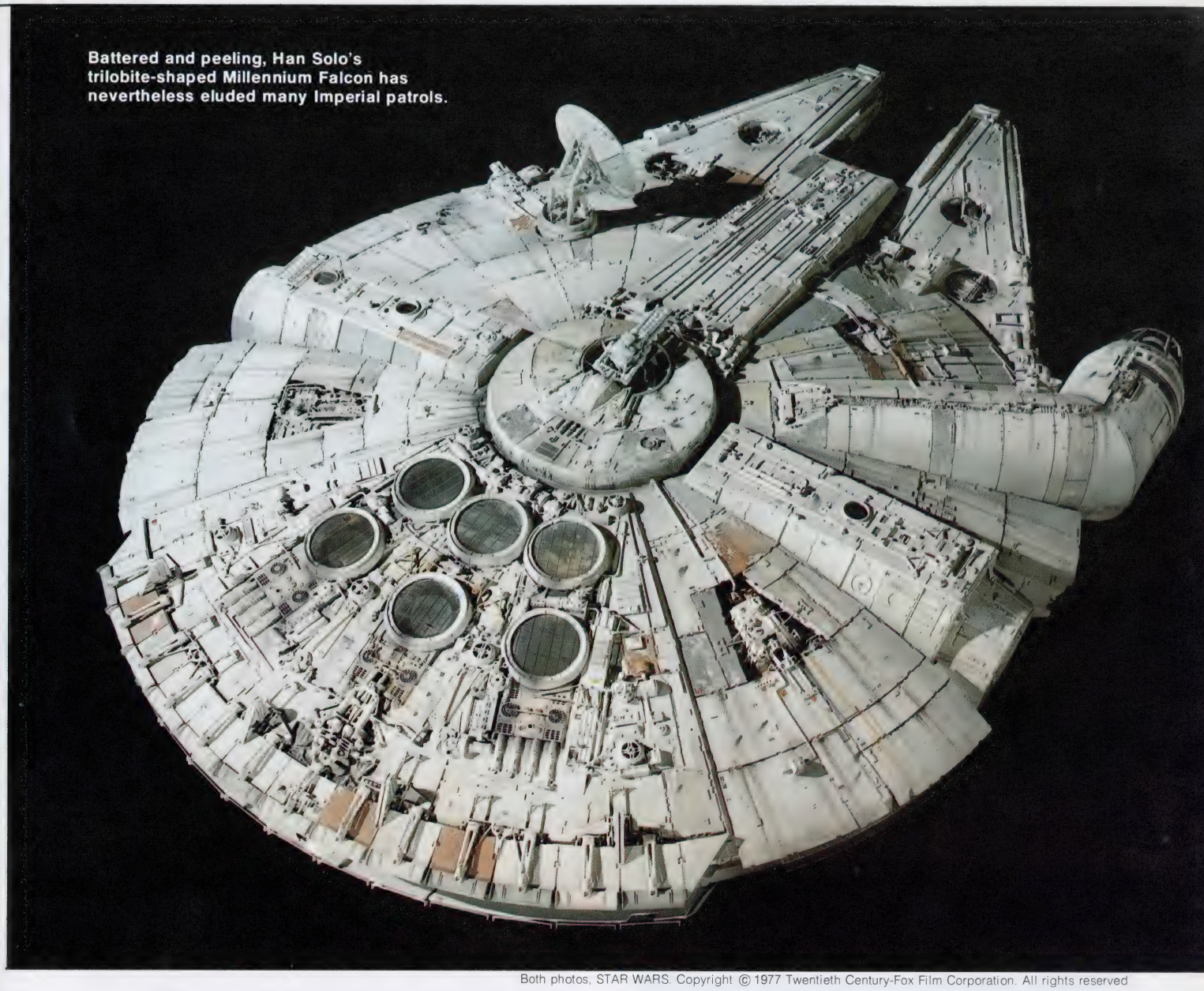
like patty-cake. From their secret hiding place on one of the planet Yavin's moons, the rebels pick at and sting the Imperials with everything at their disposal, including an outnumbered fleet of one-man fighters that are somehow reminiscent of the plucky R.A.F. soaring up to butt heads against Nazi bombers.

What catapults the plot from the commonplace to the sublime is the genius of writer/director George Lucas, who demanded a "well-used" universe for his film. No matter how extravagant their derring-do, the heroes always seem to have dirt on their shoes and a threadbare look about their clothes. All well and good. What really captivates audiences (modelers in particular) is the revolutionary appearance of the spacecraft. Totally absent are smooth-skinned saucer contours and streamlined fountainpen shapes normally linked with science fiction films. What do we have in their place? *Believable* spaceships, many of which have about as much cosmetic appeal as a secondhand car.

In contrast to the pampered vehicles of the Imperial fleet (the bad guys), all ships belonging to the rebels (the good guys) look weathered, beat up, and worn. They're discolored with dirt and grime from endless planetary landings and take-offs. Their burnt and scarred hull plates testify to scores of previous battles. They unabashedly display areas blackened by engine exhaust. Much of their piping is exposed, as are many of their engine parts. They're magnificently angular, practical, and functional, projecting a scorn for mere appearance. Their design not only reflects the reel world of space, but NASA's no-nonsense know-how with the *real* world of space.

The opening chase scene of the rebel blockade runner trying to flee a much larger enemy ship sets the pace for the entire film, immediately establishes an "us versus them" syndrome, and introduces the first two mindblowing spaceship configurations.

The Rebel Blockade Runner ——— Princess Leia Organa's starship suggests a dimly remembered past when spaceships were designed with wedding-cake flair and character. This outdated vehicle — wearing its age with grace and dignity — has an elongated body replete



Battered and peeling, Han Solo's trilobite-shaped Millennium Falcon has nevertheless eluded many Imperial patrols.

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with interesting shapes and angles. It was originally intended to be Han Solo's pirate ship but was soon deemed too pedestrian for that role, as well as too similar to *Space: 1999's* Eagle. Therefore, it's used as a "throwaway" for the initial hare-pursued-by-the-hounds sequence in which it's inexorably overtaken and lifted, via force beams, into the bowels of an Imperial Star Destroyer.

The Imperial Star Destroyer ——— This wedge-shaped leviathan of space used by the evil Empire is thousands of feet long and as sinister in appearance as a cobra flicking its forked tongue in and out. When it first soars overhead, filling the entire screen with its massive presence, it elicits oh's and ah's from the intimidated audience. Imperial Star Destroyers ceaselessly patrol the *Star Wars* galaxy, relentlessly enforcing the imposed dictatorship.

One of those opposing the Empire is a maverick young space smuggler named Han Solo, who inadvertently lets himself become a pivotal figure in the rebel revolution, though he plays this role, at first, purely for mercenary reasons. Han is a reluctant hero who comes through when the chips are down, aided by Chewbacca, the shaggy Wookie. His souped-up Corellian freighter — the *Millennium Falcon* — is one of the most fascinating ships in the film.

The Millennium Falcon ——— This oversize, one-of-a-kind "hot rodder" makes supralight jumps into hyperspace whenever pursued by authorities: a capability not without peril since accurate navigation at such velocities is difficult. A second-rate pilot might find himself slamming through the flaming heart of a star, crashing into a suddenly looming planet, or disintegrating into subatomic nothingness in a black hole. But Solo is an unexampled pilot, and his ship is a first-rate craft.

Though it's fast, the *Falcon* is no beauty. Loading mandibles protrude from its bow, and its stern is crammed with a doctored-up propulsion system. For attack and defense purposes, its topside and bottom-mounted turrets are equipped with laser cannons. The unlikely looking spacecraft plays a key role in *Star Wars,* carrying the rebel protagonists in and out of Imperial

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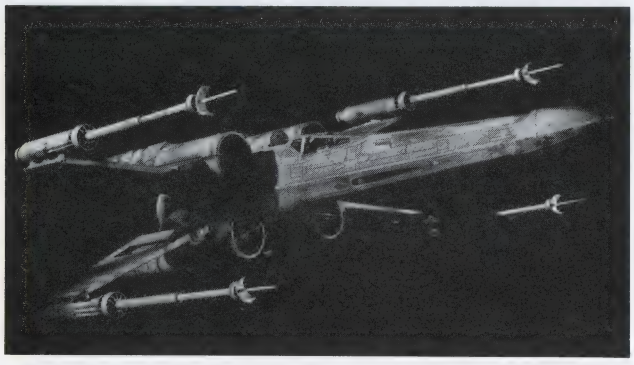
Rebel X-wing fighters, using tactics similar to those of World War II aerial combat, peel out of formation for attack on Death Star as Y-wings follow.



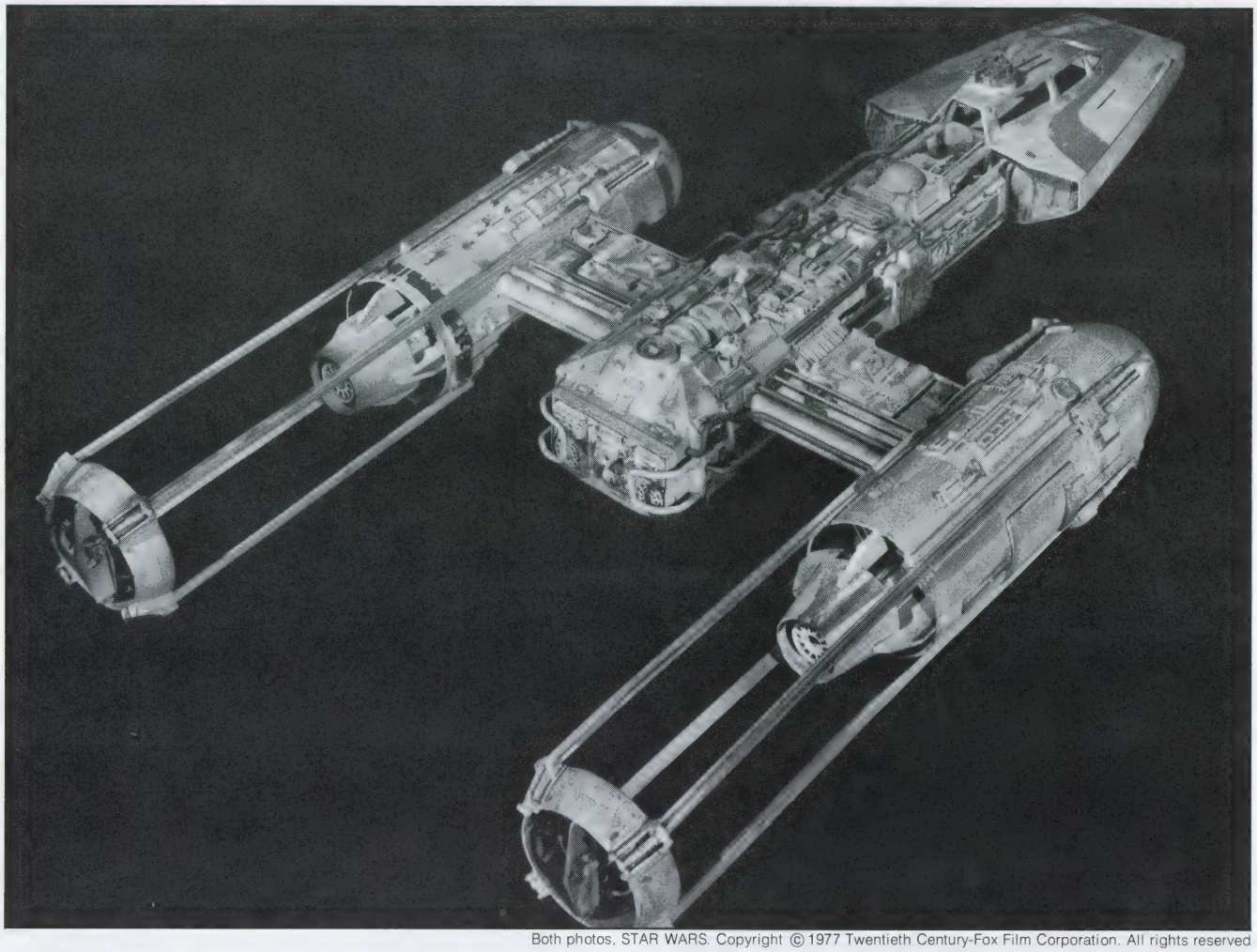
entanglements, and ultimately coming to the aid of Luke Skywalker as he destroys the giant Death Star in the climactic battle.

Just as the Falcon may be somewhat shabby, so is the rebel fleet of X-wing and Y-wing fighter craft. As mentioned in the first paragraph, each looks as though it has been drop-kicked around a football field — and, in a sense, it has. In observing the screen's slam-bang encounters, one surmises these one-man ships resemble poor relations because they see an incredible amount of day-in-day-out action which causes endless, hurried repair work. Devoted mechanics — who faithfully keep moving parts, propulsion systems, and weaponry in well-oiled shape — have time only to splice bare replacement panels into the skinwork without worrying about such niceties as applying touchup paint.

The mechanics' ceaseless efforts are rewarded by the fact that these formidable fighters can blast skyward from underground hangars in a split second, and can go 15 rounds with anything their size or bigger. A testimony to the once-large size of the rebel fleet — now worn down by attrition — is the extensive use of cannibalized parts for repair work. Let's examine these mighty mites in more detail.

X-wing fighter ——— Each X-wing has a slender, 29-foot body terminating in a quad of fuel-burning rocket engines for space travel, plus air intakes for atmospheric flight. Its wingspread spans 25 feet. The horizontal wings, which provide lift within the atmospheric envelope, separate into an "X" ("guns at ready") position once the fighter enters the near-vacuum of space. The X-wing has four wing-tip laser cannons for maximum firepower plus proton torpedoes, which are blasted from tubes flanking the fuselage and — in the film's climactic struggle — are used to destroy the Death Star battle station.

The X-wing is a one-man ship only in the sense that a solitary human occupies the cockpit. But that human



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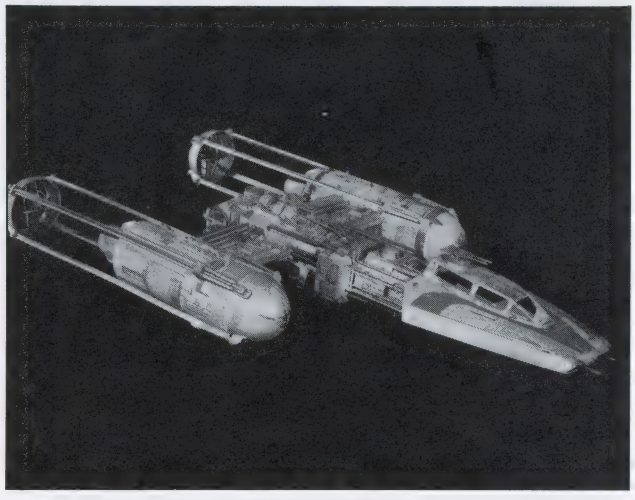
Y-wing nose represented streamlining that once extended length of craft, but was discarded to ease maintenance. Model is light gray with yellow stripes.



isn't really alone. Squatting in an external aperture behind the cockpit is a highly programmed R2 droid unit, whose function is to serve as an onboard mechanic and troubleshooter. It may have a metallic exterior instead of a soft skin, and complicated electronic circuitry rather than nerves and blood vessels, but its "fix everything" presence enables the pilot to focus his attention and reflexes exclusively on fighting.

For firing the lasers, the pilot has avionic help in the form of a half-manual, half-automatic gunsight with electronic crosshairs. For firing the proton torpedoes, the pilot has fully electronic computerized targeting in a pull-over head-up display (although Luke Skywalker eschews the computer for the more accurate guidance of the "force" in releasing the proton torpedo that destroys the Death Star).

Defensive equipment includes a warning scope on the control panel and built-in deflector shields which can be angled in any direction.

The offensive armament of the X-wings — in particular the proton torpedoes and targeting computer — suggests that the fighters were designed as much for attacking fixed or planetary targets as they were for engaging other ships in air-to-air or space-to-space combat. The heavily weathered appearance, in addition to suggesting frequent use combined with the capability of maintaining only priority items, also indicates a preponderance of atmospheric missions (on which weathering would be extreme), perhaps against planetary occupational forces of Imperial stormtroopers.

Finally, an irony concerning the X-wings: They are not referred to by that name at any time in the movie (neither are the Y-wing nor TIE fighters mentioned by name). The

name grew out of informal use at Industrial Light and Magic, the firm which filmed the special effects. By the time the novel appeared that was derived from the screenplay, the name X-wing had caught on and was used prominently; in fact, the X-wings at one point are given an even more formal designation: Incom T-65.

Y-wing fighter ———The Y-wings are less in number than the X-wings and are not as fully developed as to their capabilities. The name is derived from their configuration or shape. In the film, they make the first, ill-fated attack down the Death Star's trench, with results somewhat reminiscent of Torpedo Squadron 8 at the Battle of Midway.

The climactic battle scene that eventually — and shatteringly — wipes out the awesome Death Star is depicted with different details in the book than in the movie. In both, the rebel attack fleet is launched from a junglelike moon of the gaseous planet Yavin. In the book, the attacking fleet is identified by the Imperial defenders as containing at least 30 ships. Four squadrons, in fact, are launched, with a mix of X-wing and Y-wing fighters. In the initial formations, Yellow Squadron covers for Red on the first run, and Green covers Blue on the second pass; after that it's pretty much every man for himself. Luke Skywalker's ship is "Blue Five" and has blue markings.

During the prolonged attack, individual rebel pilots identify themselves, via their helmet transceivers, as "Yellow One," "Red Three," "Green Four," and so on.

In the film, Luke's ship is "Red Five" and has five red markings on its wings. Only X-wings from Red Squadron are shown, although ostensibly other X-wing squadrons take part in the battle. The few Y-wings shown are part of Gold Squadron.

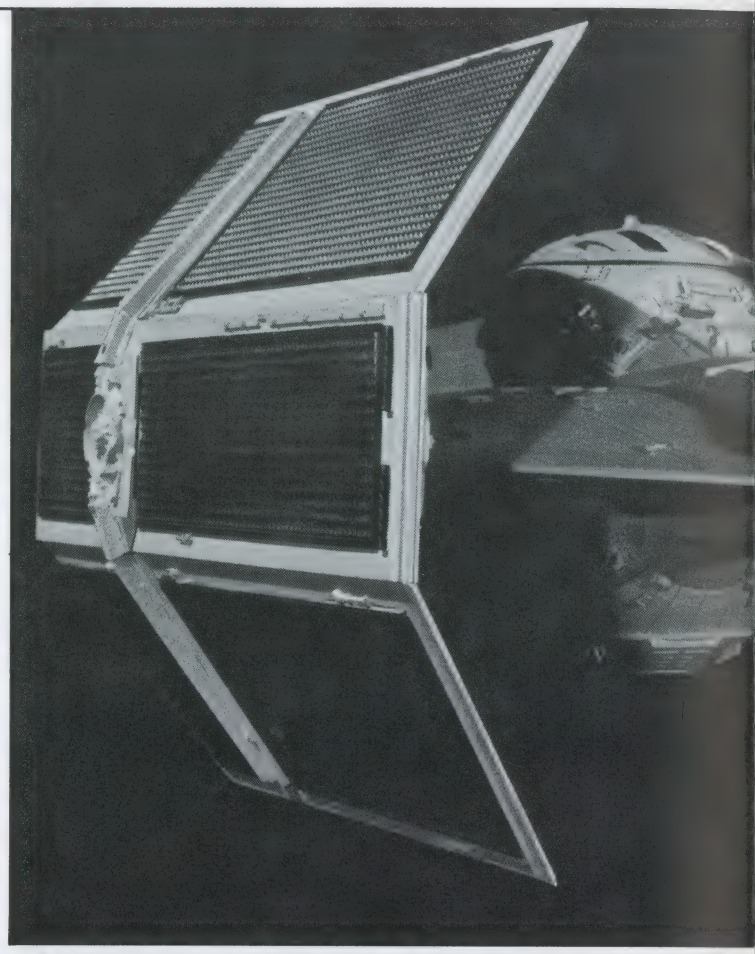
In the movie, Imperial defenders count 30 ships comprising the attacking force. In both book and film, most of the attacking fleet is wiped out — some by the Death Star's defensive guns but most by defending TIE fighters led by Darth Vader.

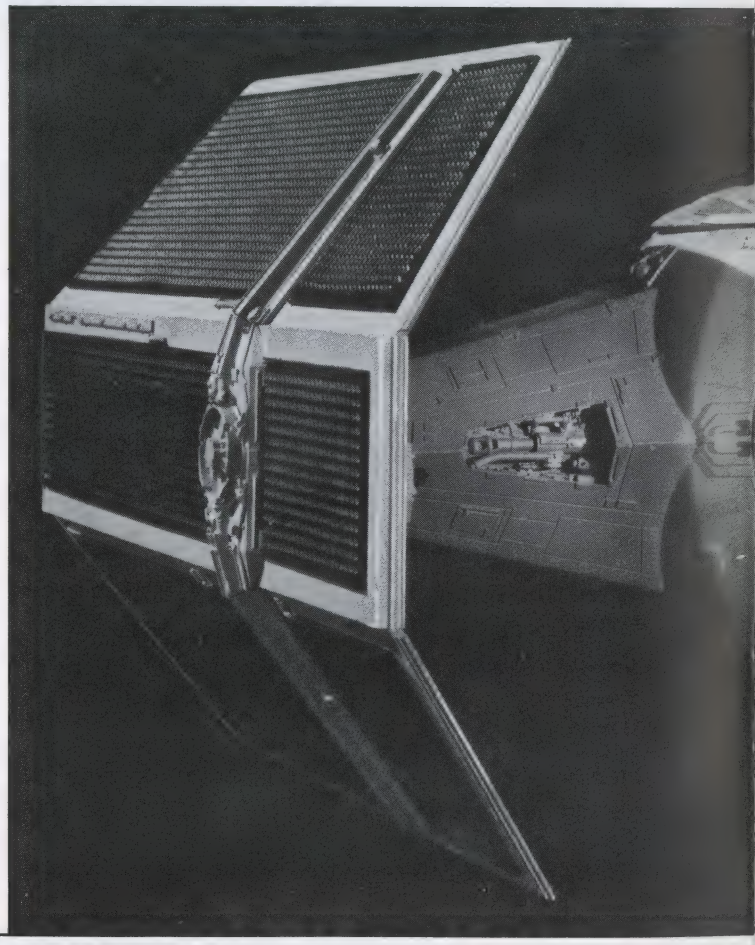
As the Death Star atomizes in a holocaust to end all holocausts, the novel depicts several X-wings and Y-wings, plus the *Millennium Falcon* (which made a ninth-hour appearance to disrupt Darth Vader's pursuit of Luke Skywalker's deadly torpedo run), making the return to the rebel base.

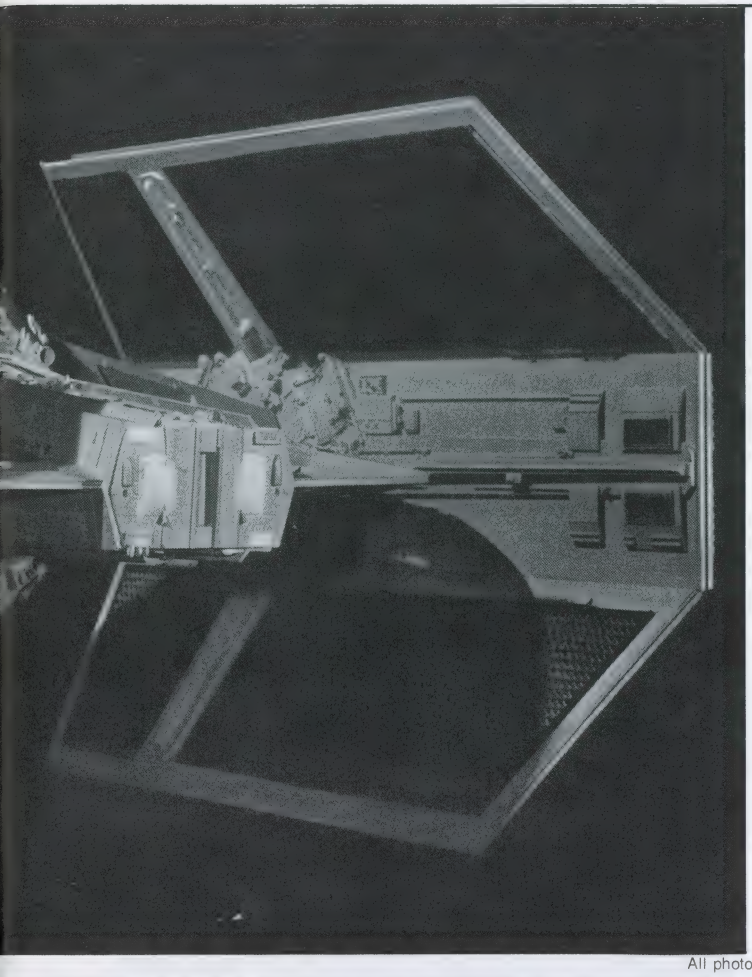
Before the curtain is yanked down by Luke, the rebel fleet dogfights with scores of deadly TIE fighters — the insidious Empire's counterpart of X-wings and Y-wings. Let's see what makes the TIE so fearsome.

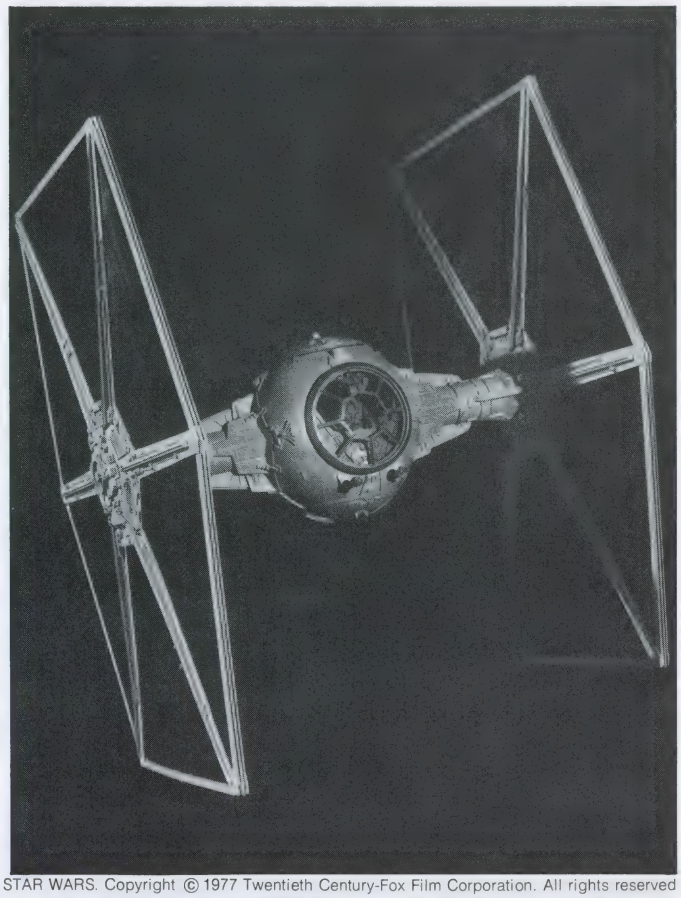
Imperial TIE (Twin Ion Engine) Fighter ———Unlike X-wings and Y-wings, TIE short-range, one-man fighters are basically employed in space's semi-vacuum, not within planetary atmospheres. Again, unlike the motley-looking X-wings and Y-wings, they're store-window clean, indicative of the fact that they're transported hither and yon in the massive bellies of Star Destroyers, from which they're launched to do sentry and reconnaissance duty, to patrol the Imperial forces' outer domains, to provide defensive protection for the all-important Death Star, and to summarily slap down any stirrings of revolt.

An individual TIE is menacing in appearance, with two laser cannons mounted just below its spherical cockpit's circular viewport. Support columns stretch out from each side of this bubble, firmly clasping two oversize, hexagonal, solar-energy-gathering sails which transmute photons into the considerable quantities of









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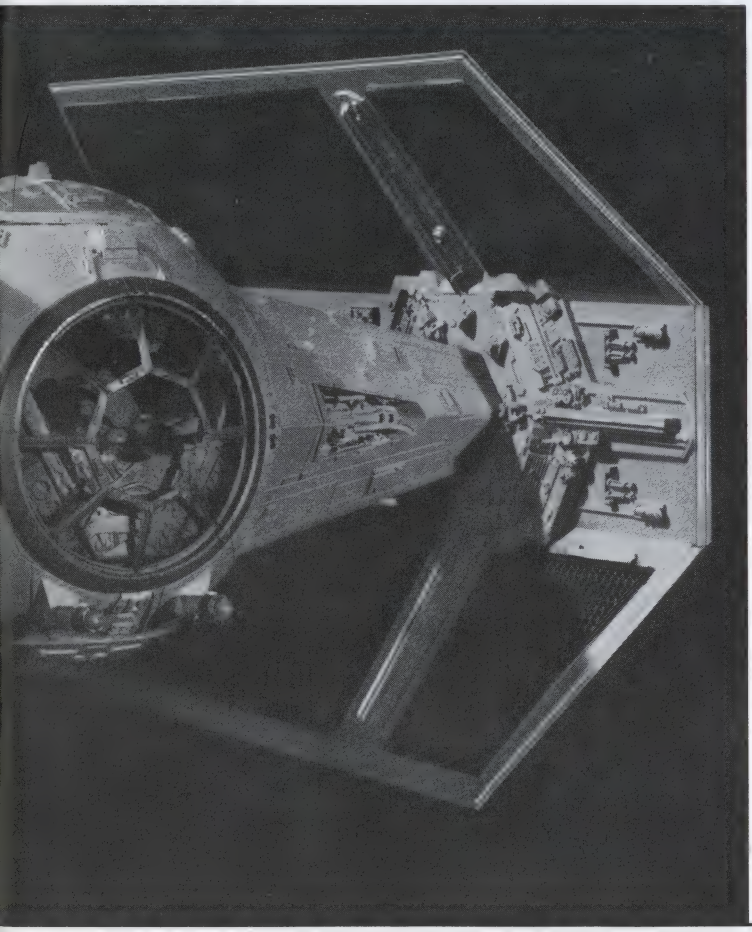
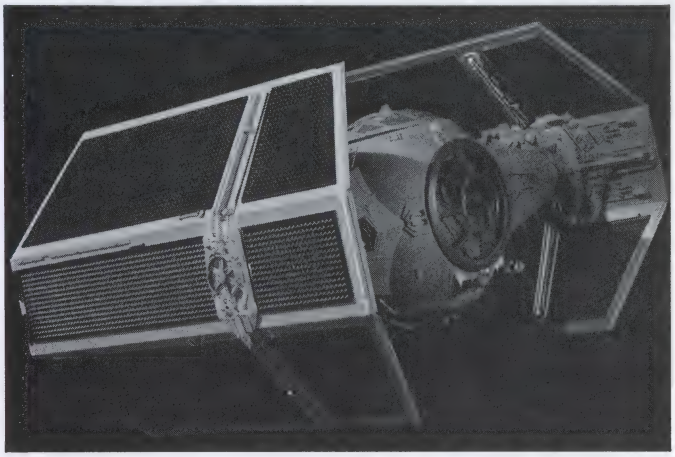




In order to eliminate unwanted reflections during filming, no glass was used on canopies of studio models of the two versions of the TIE fighter. Laser cannons distinguish "top" from "bottom."

electricity needed to operate the double ion engines. In the two engines, positively charged atoms are accelerated at tremendous speeds by electrostatic fields, then neutralized by regaining their electrons a split-second before being ejected as an enormously forceful propellant through a rear nozzle.

Darth Vader, the black-clad, breath-masked chief villain of the story and the Empire's most ruthless agent, flies a modified version of the standard TIE fighter. On his customized ship, the side solar panels are angled in

at the top and bottom, reducing the size of the total configuration for better maneuverability in tight situations. An added aft section allows for twice the normal engine capacity. Vader's ship was designed this way by Industrial Light and Magic, not only to intensify his sinister aura but — for the sake of the audience — to render his ship distinguishable from other TIE's during the Death Star donnybrook. Vader is the only Empire personage to escape, tumbling off into outer space after his fighter is knocked out of control. (Without being told, the audience instinctively knows he'll be heard from again.)

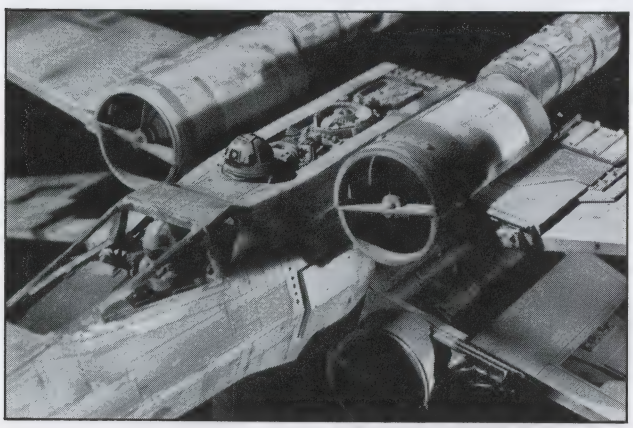
An interesting sidelight on all this is the strange status of space-age technology presented in the story. Though there are deflector shields, landspeeders, tractor beams, unbelievably sophisticated androids, holographic messages, hyperspace propulsion devices, and other evidences of advanced know-how, there are no guided missiles, even of the garden variety. In the frequent shootout confrontations, whether up close or over considerable distances, attackers and defenders act like gunslingers in Class B Westerns — forever aiming, shooting, and missing. It's as though cavemen had invented differential calculus but persisted in carrying stone hand axes. Perhaps this can be explained by the fact that the action takes place in the distant past rather than the distant future, and the levels of knowledge extant, though stratospherically high, are as spectacularly uneven as a roller coaster.

THE DESIGNS of the X-wing, Y-wing, and standard TIE fighters (as well as those of the Imperial Star Destroyer and the rebel blockade runner) originated with Colin Cantwell. According to him, the X-wing's and Y-wing's atmospheric capabilities required a horizontal wing configuration for flight near planetary surfaces. Once into space, he had the former's wings "open up" for two reasons: visual excitement and easy identification.

In designing the evil-looking TIE fighter, he tried to mirror what he thought the mental-set of a totally alien culture might be. Darth Vader's customized TIE fighter was not one of his designs, but spontaneously evolved during production as a convenient means of pinpointing the Vader ship when it zapped about on the screen.

Cantwell built prototype "study" models of his designs out of styrene and model-kit parts. Later these were translated into detailed drawings by Joe Johnston. The actual miniatures used for filming were painstakingly assembled under the direction of Grant McCune, chief model-maker of Industrial Light and Magic of Van Nuys, Ca., the firm which revolutionized special effects photography during the course of filming *Star Wars* (Special Photographic Special Effects Supervisor John Dykstra won an Academy Award, as did ILM's Richard Edlunds for photography, Robbie Blalack for opticals, and McCune for the miniatures).

From the Cantwell originals and Johnston drawings, McCune "edited" the actual film miniatures for the "stage." Such considerations as size, shape, and interior room for electronic devices influenced the construction of the miniatures. For example, as conceived, the X-wing was a sleeker, smaller ship. However, its aft section and wings had to be enlarged to accommodate the motors and wires that enabled the wings to flare open. Because of this, larger engines were added for symmetrical balance.



Of the five X-wing stage models, three had motorized wings. All five had air-cooled quartz lights in each of the four engines, plus LED (light-emitting diodes) cockpit interiors. To provide focal points for optics which were later added to the film, lights were fitted into each wingtip laser cannon and fuselage-flanking torpedo tube.

The miniatures were built using parts from original molds and parts salvaged from hundreds of surplus plastic kits.

Each model's surface was non-reflective, and of a special color, so as not to interfere with the blue-screen filming process. A Johnston sketch envisioned a bubble canopy for the X-wing, but a flat glassless canopy had to be used to avoid a light reflection that would have been detrimental (by showing a hole in the ship) to the blue-screen process.

Although the X-wings and Y-wings were weathered because Director George Lucas wanted them to look real, McCune also noted, "It is a lot easier to build a dirty model than a clean one."

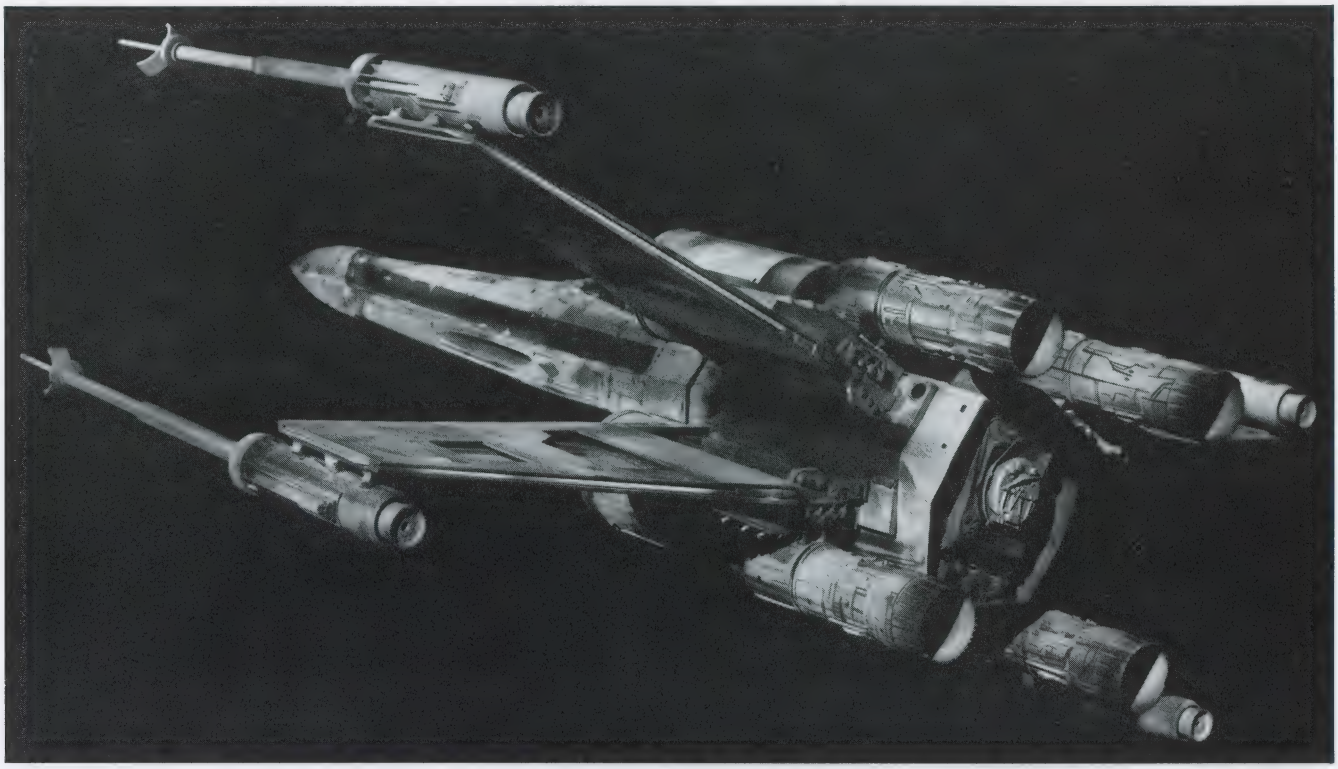
Painting procedures were radically different from ones plastic modelers might use. The X-wings were first painted with a white enamel automotive primer to create a hard undersurface that couldn't be scratched away. Liquid frisket was dabbled about with a paintbrush, and then the models were sprayed with Floquil Railroad colors — sometimes with airbrushes that hadn't been cleaned for weeks. With removal of the frisket, the undersurface showed through to resemble areas of extreme wear.

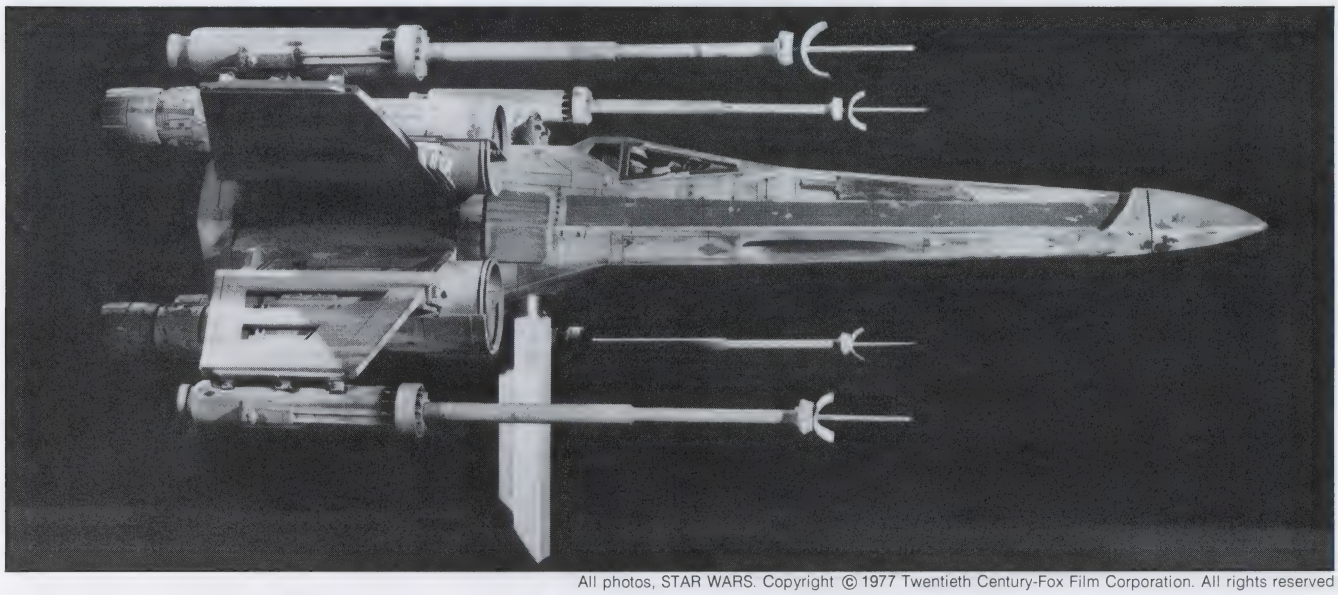
The red wing-stripes were added at the suggestion of Johnston to help tell one X-wing apart from another.

Finally, grease and grime colors were dipped into thinner and flowed across the model with a brush. Steel wool was used to create further weathering and to rub down areas that needed to be redone. "Sometimes," admitted McCune, "you're hard put to know when you've gone far enough."

Nine X-wings were made from silicone rubber molds and back-cut for use in scenes in which they had to explode. Finalized model designs were sent to John Barry, at EMI Studios in London, England, to be used as guides in building full-scale ships for hangar scenes.

All the miniatures featured built-in armatures that could be attached to an external motion device — at a variety of angles — to realistically simulate in-flight





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movement. A question posed by one modeler concerned the location of the entrance hatch on the TIE fighter. The studio models had three hatches — top, bottom, and back. That's because the models had mounting holes in those positions, and the hatches became a convenient way to cover the two out of three mounting holes not being used during filming.

The TIE fighters were painted a light gray-blue, almost a powder blue. However, because gray values are lost in film duplicating, the TIEs appeared much whiter on movie-house screens.

Five stage versions were made of TIE fighters, including Darth Vader's. Each had LED-lit interiors and engine effects. The engine effects were added more as a device to give the fighters direction on the screen than as a preconceived part of the design. Sixteen TIEs of the exploding type were also built.

The final tribute to the modelbuilders and special effects people might well be the fact that the nicknames ("studio jargon") that they coined for the ships for ease of reference spread like wildfire through the public awareness. Thanks to them we have such colorful appellations as X-wing and TIE — names that never were heard in the movie. One nickname, however, that did not escape beyond ILM walls was the jargon for the *Millennium Falcon:* the "pork burger."

Masking and painting the TIE

KIT: Darth Vader's TIE fighter from *Star Wars*
MANUFACTURER: MPC, U.S.A., Kit No. 1-1915
SCALE: Unstated; approximately 1/24
DIMENSIONS: Wing length—6 13/16″; Fuselage length—5¾″; Wingspan—7⅞″.

Don Klein

THE BATLIKE Twin Ion Engine (TIE) fighter is the better of MPC's two *Star Wars* spacecraft. The fit of all major sections is excellent, and the detail is intricate and well-executed throughout. The recessed, cut-in panel separation lines — which, in terms of making the molds, is the more expensive way to do the job — are superior in all respects to raised panel lines. These greatly help the realistic appearance of the completed model, and they facilitate panel masking for painting the model in several subtly different gray shades.

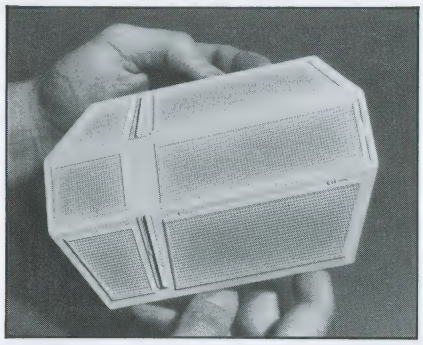
The areas on which I concentrated with this modeling job were panel masking and interior detailing. The main objective of the panel masking and painting was to make this model interesting and bring out its detail *without* a weathering treatment. I took on the cockpit detail as a challenge, mostly because the large scale of the model lends itself to such detailing without making the detail gross or clumsy. The cockpit can be completed as a subassembly and slipped whole into the model, another factor which makes the job easy.

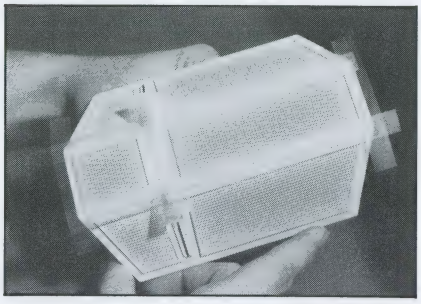
Masking and painting — After carefully examining the model, removing the parts from the molding trees, and cleaning away all wisps of flash and mold parting lines, I tested the major parts for fit. I then airbrushed all parts with a slightly grayed white — in this case, Humbrol underside white mixed with a few drops of Pactra tinting black.

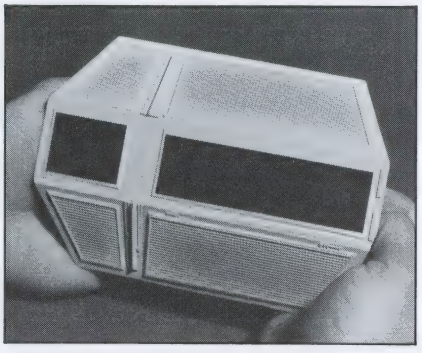
After giving this coat a couple of days to dry completely, I masked the areas between the solar panels on the angled "wing" structures with Scotch Brand Magic Transparent Tape. This masking was easy because the solar panels had straight edges that could be masked with tape right off the roll. I then airbrushed the waffle-texture solar panels with flat black.

Masking the multi-shaded panels on the main body section of the TIE fighter is more complex, but not necessarily more difficult. I started by laying strips of the Scotch transparent tape over the entire fuselage. When the fuselage was covered, I used a sharp No. 11 X-acto knife blade to cut through the tape around all the panels that I wanted to airbrush in contrasting shades of gray. I used the fine grooves between panels as guides, placing the knife point in them and lightly slicing through the tape. This done, I pulled the tape off the panels, airbrushed the appropriate color, let dry, and remasked before peeling off another set of panels for the next color.

Therefore, the sequence should be:
(1) cover entire fuselage with transparent tape,
(2) cut through on all panel lines,
(3) peel away tape to expose panels that will be one color and airbrush,
(4) remask and recut panel lines,
(5) peel away next color and paint again.







Solar panels dried two days before masking with transparent tape, then were airbrushed flat black.

For small raised details, I used a brush to paint the contrasting grays. The grays I used were Pactra rebel gray and Pactra panzer gray.

This is a good place to stop and add a word or two about applying and removing masking, whatever kind you use. The idea of any masking, of course, is to cleanly separate colors without damaging the paint underneath the masking medium. Here are some tips to help you accomplish that. First, off-the-roll masking tape has a fuzzy, indistinct edge. It's certainly good enough for full-scale subjects such as automobiles and motorcycles and house windows, but the fuzzy edge is alarmingly apparent in our scale models. You can improve on it somewhat by using Scotch Magic Transparent Tape, which has a much sharper edge. Or, you can apply your masking tape to a sheet of glass and cut a sharper line with a single-edge razor blade or hobby knife held against a steel straightedge. This will give you a cleaner edge to the tape, and cleaner separation lines between colors.

Applying your tape to glass first also removes some of the stickiness from the tape adhesive, and this is good too. Most tapes are, if anything, too sticky and will pull paint.

When you apply the tape, press it down only firmly enough to make a good seal along the separation line, and press down *only* along the line. The idea is to achieve the *minimum* bond between tape and paint needed to prevent the second color from getting under the tape. The less force used to bond the tape to the paint, the less likely the tape will pull the paint beneath it when the masking is removed.

Where large areas away from the separation line must be masked from overspray, use newspaper instead of masking tape. Use tape along the separation line, of course, but slip a sheet of clean newspaper under the opposite edge of the tape and use it to *wrap* the model.

Leave masking tape on the model for as little time as possible. This means you should mask a model, paint the second color in the same work session, and remove the masking as soon as the second color is set — not dry, just *set*. If the masking is only on the model for two hours, that's good — if only for one hour, that's better. The longer the masking remains on the model, the more it bonds to the paint coat beneath it, and the more liable it is to pull the paint when it is removed. So, do your masking, paint, and remove the masking. Also, make sure the paint coat that you mask over is cured. This may mean waiting two days or even a week between colors, but the alternative is a ruined model.

When you remove tape, peel it off by pulling the end of the tape directly back over itself. This will mean that the tape is at close to a 180-degree angle where it is

peeling off the model. This extreme angle places the stress of tape removal on a very small surface area of paint. This, in turn, minimizes the total adhesive pull on the paint, which can be a lot if you pull the tape straight away from the surface. It's similar to trying to hold up a heavy object with tape — you can't do it with a narrow band; but if you use wide tape or several narrow strips, the total adhesive power will do the job. We want to minimize the holding power here.

Getting back to the TIE fighter, after completing the major panel masking and painting, I used a 000 spotting brush to pick out details such as holes, sockets, and fastening devices with flat black and dark gray.

Other than the cockpit detailing, the only modification I made to the model was to omit the landing gear parts. Landing gear is in the optional category on any model, and I omitted it here to emphasize the ship's horizontal lines.

Cockpit detailing — The cockpit parts in the kit provide good molded-in detail but lack the three-dimensional look. The biggest drawback is the lack of a cockpit seat. I omitted the Darth Vader figure, so my cockpit detailing involved scratchbuilding a pilot's seat from sheet plastic and adding control levers, instrument dials, indicator lights, and hand grabs from various bits and pieces of stretched sprue.

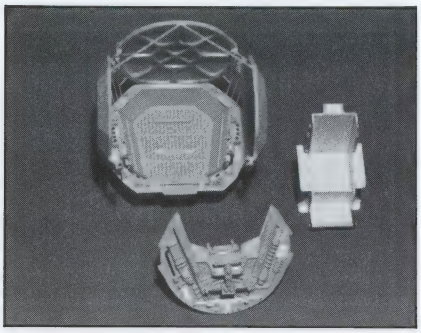
The seat is the first order of business. I made mine from .025" sheet styrene and added cushions made from $^1/_{16}$"-thick stock. The edges of the cushions are rounded, and their glossy red finish simulates fabric. I made handles on either side of the seat and added dials and indicator lights made from stretched sprue.

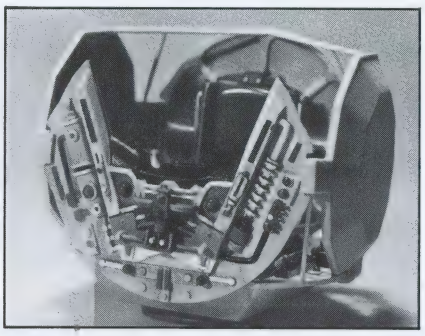
The dials and indicator lights in the remainder of the cockpit were made from bits of stretched sprue, too. The trick is to slice off bits of sprue until you have some thin round slices. You may have to make a dozen slices to get three good dials or indicator lights, but the raw material is cheap. After painting the dials and indicator lights in various colors, I made them stand out in the flat interior by touching them with a drop of Devcon "5-minute" Epoxy applied with a toothpick. Each drop of epoxy dried in a transparent bubble shape, giving dimension to the features on the instrument panel.

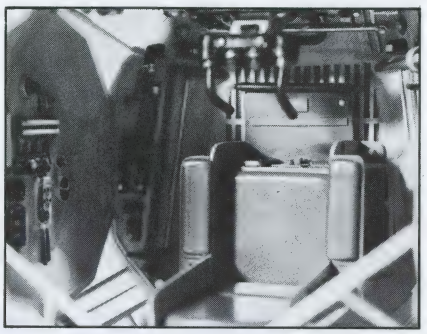
The detailing is freelance, because the available drawings don't offer much in the way of detail for this portion of the ship. The idea is to make the cockpit look functional and interesting — how you do it is your own business, so have a ball!

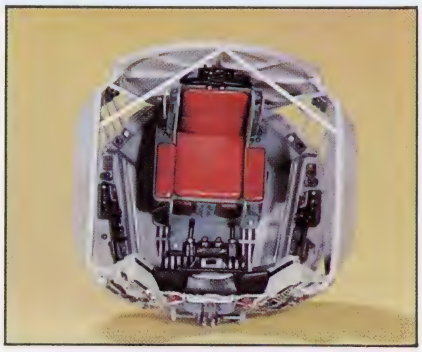
I also picked out the molded-in cockpit detail with various gloss and transparent paints.

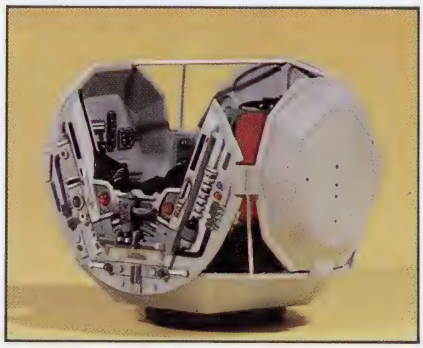
I did not weather the TIE ship, other than adding a few small streaks around what represents operating machinery. Why? Well, this ship is the personal fighter of Dark Lord of the Sith Darth Vader, and it's supposedly the most advanced of its type. So it's new, and it probably gets tender loving care, sort of the general's personal jeep. Also, it doesn't make any atmospheric flights as the X-wings do, so it isn't subjected to the ravages of wind, dust, and water.

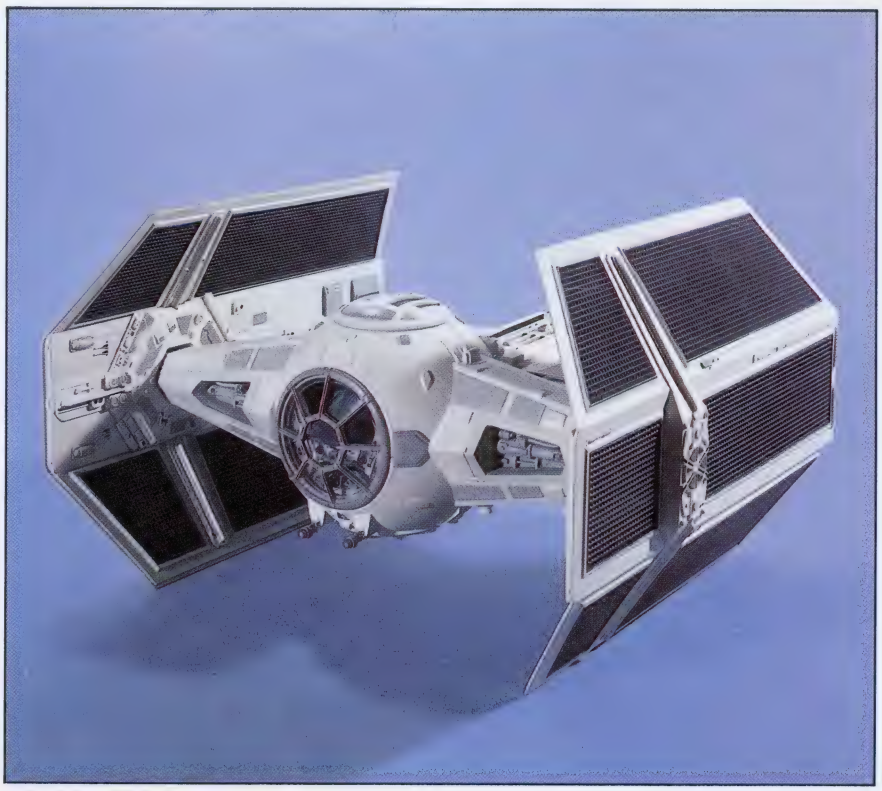




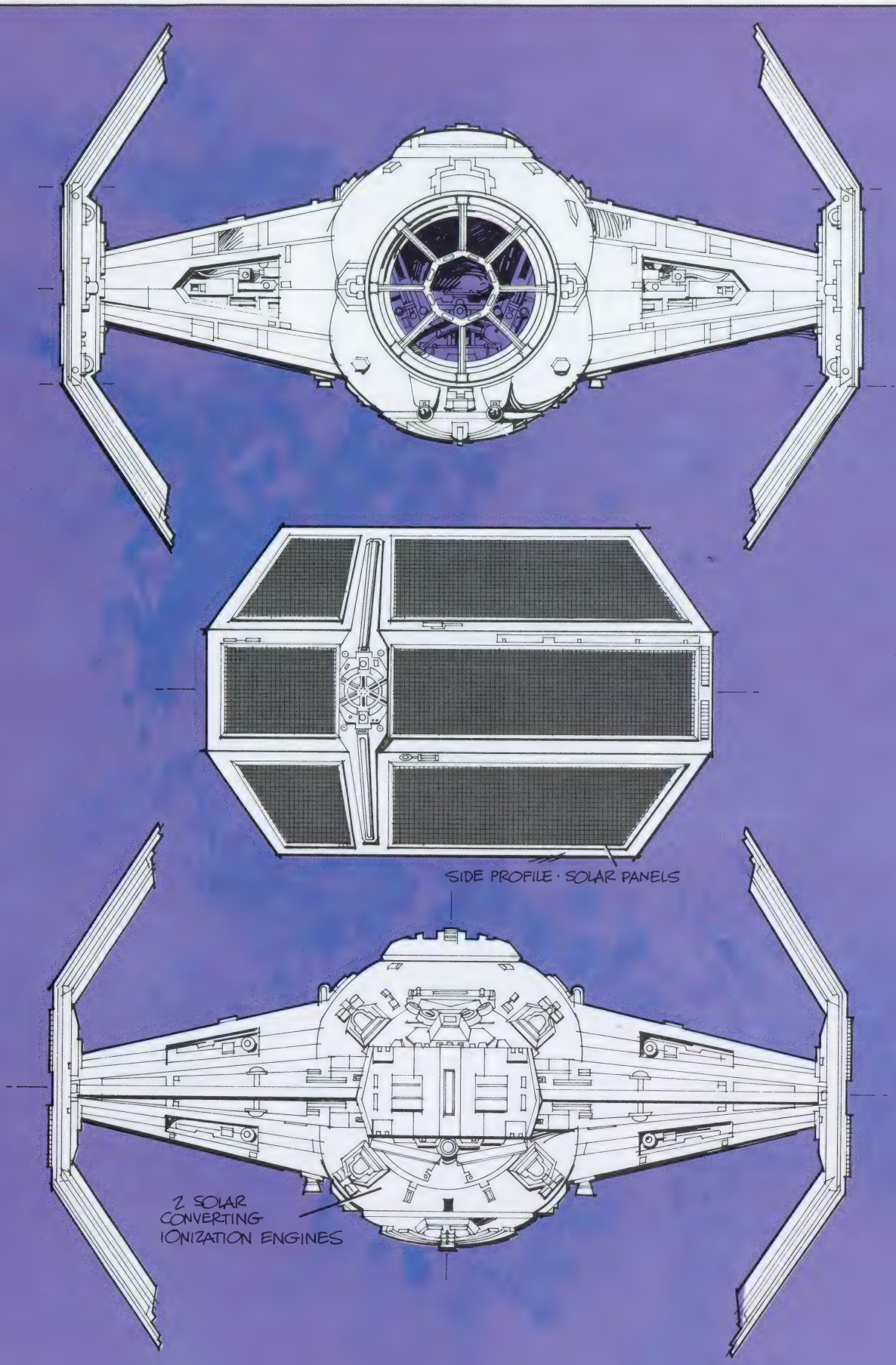




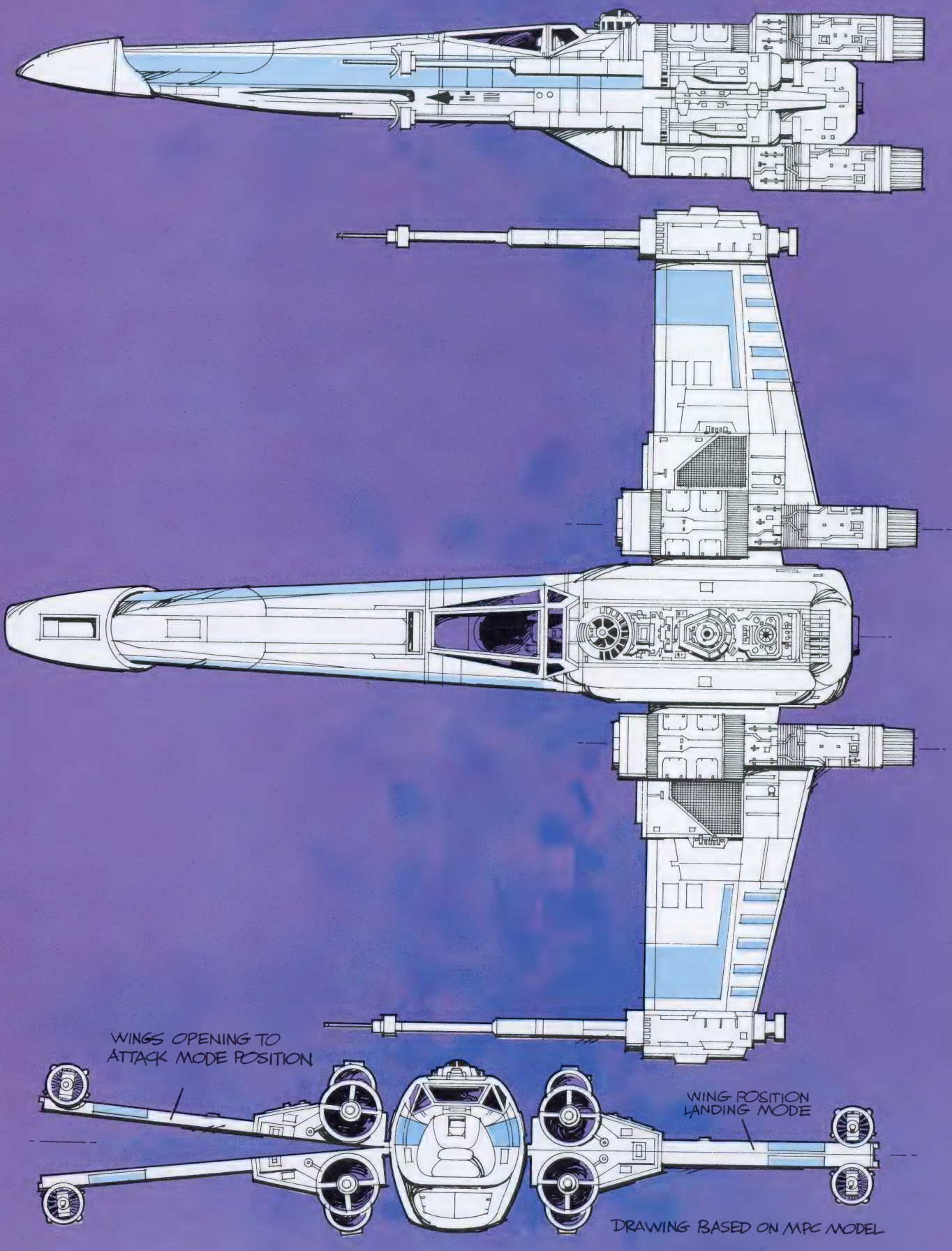




Scratchbuilt seat, dials, and indicator lights bring color to cockpit interior.



DRAWING BASED ON MPC MODEL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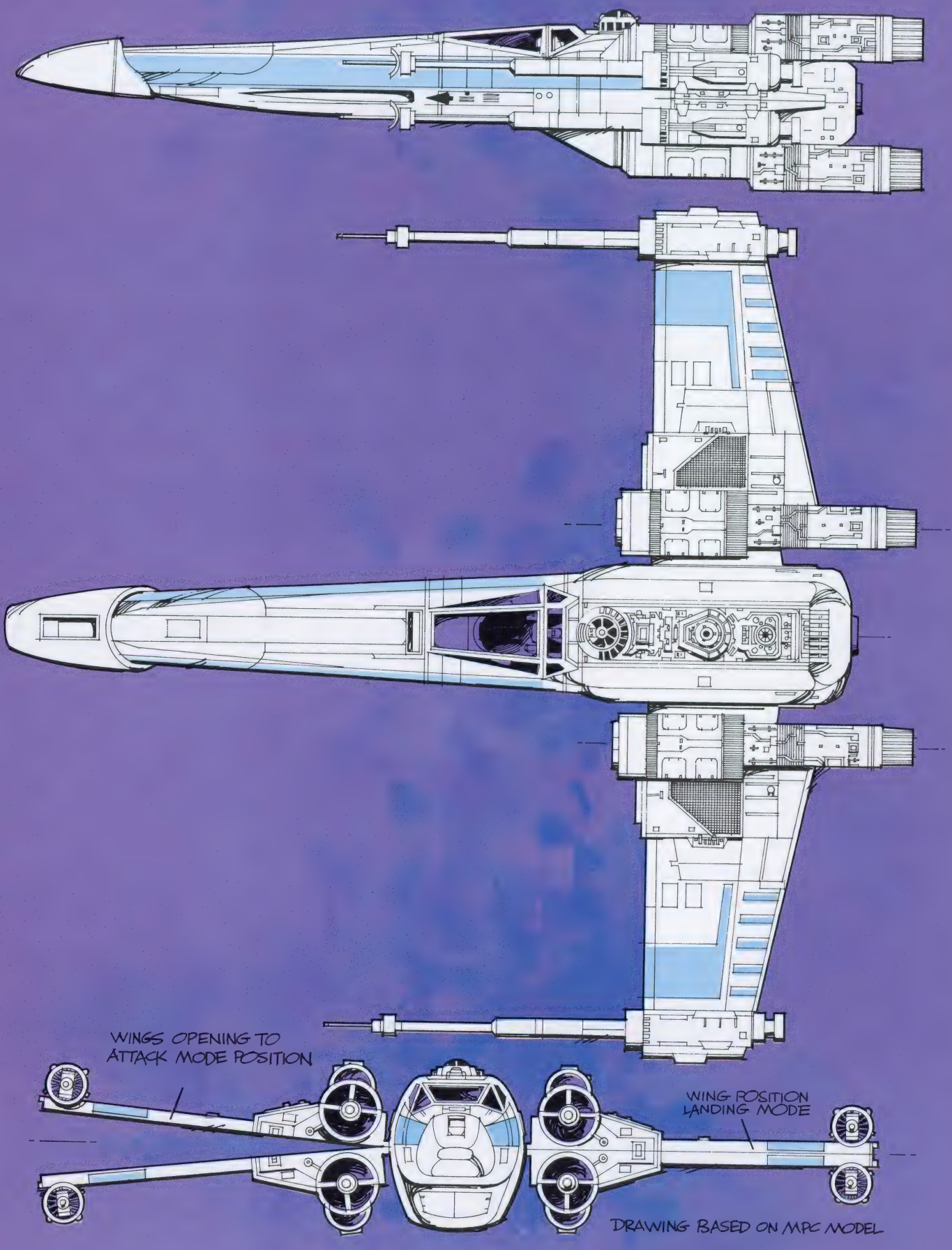
ATTACK MODE POSITION
WING POSITION
LANDING MODE
DRAWING BASED ON MPC MODEL


WINGS OPENING TO
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WING POSITION
LANDING MODE
DRAWING BASED ON MPC MODEL

Weathering is key to X-wing

KIT: Luke Skywalker's X-wing fighter from *Star Wars*
MANUFACTURER: MPC, U.S.A., Kit No. 1-1914
SCALE: Unstated; approximately 1/48
DIMENSIONS: Length—11⅞"; Height—2 9/16" (closed wing configuration, gear down); Wingspan—10 19/32"; Vertical wingspan—4¼" (open or attack wing configuration).

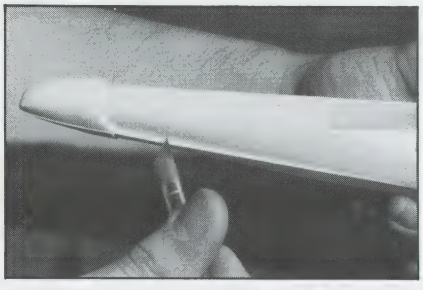
Don Klein

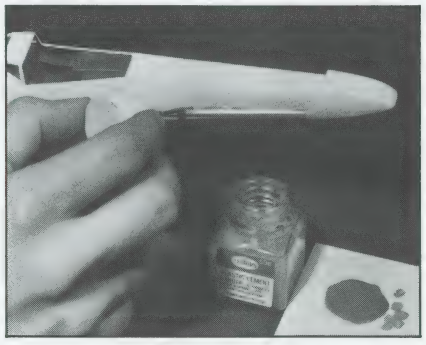
MPC'S rebel X-wing fighter from *Star Wars* is not as good a kit as the firm's TIE ship, but it is a fundamentally sound model with quality modeling work. With care, it builds into an excellent replica of the battered "good guys" ships in the movie.

I concentrated my efforts in three areas while building two of the MPC X-wing fighters. First, I set out to solve a bad mismatch problem between the top and bottom halves of the main fuselage section. Next, I added a number of minor details to the body and wings to make the model more interesting and more authentic. Finally, I chose to execute the weathering on one ship — the version with the wings in the takeoff/landing configuration and the gear down — with powdered pastel chalks, but to age the second model with airbrushed paint.

Correcting the fuselage mismatch — To start on the body mismatch problem, cement the fuselage top and bottom together, carefully positioning the top half so the overlap is equal on both sides. Make sure this bond is a solid one, and give it at least overnight (two days isn't too long) to dry.

I filled the joints between the fuselage halves with green automotive spot putty thinned with a few drops of Testors (liquid) Plastic Cement No. 3602 to make it easier to work. Check the photos and note





the shelf-like "step" where the bottom fuselage juts out wider than the top section from the cockpit forward to the nose cowling. This is intended, so don't try to fill it in. Use Flex-I-Grit sanding film, wet, to smooth your filled areas.

As usual, I filled in one or two of the panel grooves inadvertently while correcting the fuselage mismatch and had to rescribe the joint lines. Do the recutting with a No. 11 X-acto blade. Where the length of panel line to be scribed is short, you can get away with slow freehand cutting; but when the line exceeds half an inch or so, use a small steel straightedge or other piece of metal as a guide to ensure the blade doesn't wander.

The kit instructions show how to assemble the pivoting X-wings inside the body so they will move from the takeoff/landing position to the attack position. This is fine for a quick-and-dirty toylike model; but for a scale model, forsake the operating feature and leave the instruction assembly sequence behind as well. It would be almost impossible to properly work on the main body joints with the wings in the way, so my solution was to cut the wings apart, making them, in effect, four separate wing sections. This allows you to add the wings after the rest of the model has been assembled, painted, and decaled, and to add extra detail to the model wings should you choose to assemble them in the attack configuration. You trade the operating feature (of dubious value anyhow) for better access to the parts during construction and easier handling all around.

The landing gear parts on my kits were poorly molded — the old problem of mold misalignment on round parts. This kit is far from unique in this respect — it's a problem that seems to plague the majority of plastic kits. If you're looking for the ultimate in appearance, the solution is to fabricate replacement struts from plastic or brass tubing and stretched sprue, but I made do with the kit parts by carefully scraping the mold parting lines with a modeler's knife and finishing up with files to achieve a correct round cross-section.

Adding some simple details — The final modifications I made to the kit were adding several dozen small bits of styrene sheet to the body panels as extra relief detail, and rebuilding the laser cannons with stretched-sprue tips. There is nothing exacting about the detail — it's just small rectangles of .015", .020", and .025" styrene sheet cemented in place to represent access hatches, protruding junction boxes, and so on. On the attack model, I detailed each recessed area on the wings with bits of styrene sheet, sprue, and Plastruct tee-section stock.

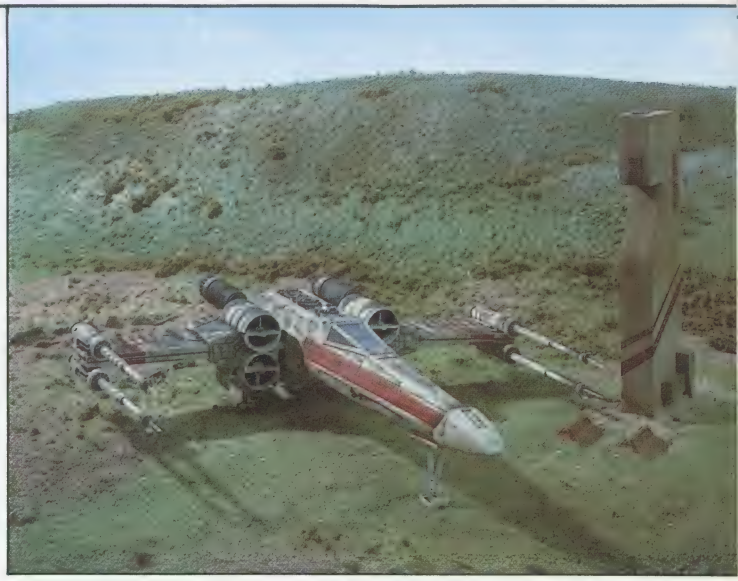
After the cockpit interiors were painted, the clear areas of the canopy were masked and the fuselage and wings airbrushed with the base color — Humbrol underside white for the landed model, a 3:1 mix of Pactra white and Pactra aero blue on the craft in the attack configuration. With the base coat cured and stable — at least two days' drying time — I added the decals, coated them with Dullcote, and started the weathering treatments by adding black ink in the cracks between the panels to accentuate them. I did this by applying Pelikan brand Plaka ink No. 70, using a fine brush. As you apply the ink, use a bit of rag moistened with water to rub away any excess. Rub toward the rear of the model so that any resulting smudge will simulate the residue of oil or fuel leakage.

Weathering with pastels — Weathering helps to blend any model into a more homogeneous whole by covering decal edges and small imperfections with a grubby film. It also enchances realism, of course, and brings out detail.

Inexpensive pastels are available both as individual sticks and inexpensive sets at most art-supply stores. Start by grinding small amounts of dark brown, rust brown, light gray, and black chalk into little piles of powder by rubbing them on a coarse file or a rectangle of medium-grit sandpaper. Don't grind much — you'll find that a little goes a long way.

Now dip your brush into one of the powdered chalk piles and dab the powder onto the model. After you first touch the brush to the model, streak the powder toward the rear, and tail off the streak to give it a fading effect. A No. 2 or 3 round sable brush is a good size for manipulating chalk. Work the powder into cracks and around the edges of raised detail, and always finish with a rearward motion. If you overdo the amount of chalk, simply brush it out, and proceed cautiously until you get the hang of the process. Start on the areas of the model that would likely be the dirtiest — the engines, on the X-wing — and use them for practice before moving on to areas where less dirt is needed.

The finishing step for a chalk weathering job is to make sure it stays put. Use a clear fixative coating to hold the powder in place and prevent fingerprints from showing. Since brushing-on a clear coating would disturb the chalk particles, use a spray can or airbrush to add the fixative. This can be an artist's matte fixative specif-



ically intended for pastels (beware this may attack the decals), or a clear flat model coating such as Testors Dullcote. Be sure to mask clear canopy areas before applying the clear coating.

Weathering with the airbrush — My attack configuration model was weathered with an airbrush, but its paint job before weathering differs considerably from the landed version. First, I brush-painted several fuselage panels a slightly contrasting gray to highlight them. To indicate sheet-metal areas that had been replaced but not repainted, I omitted four pieces of the broad red fuselage decals and painted two panels just aft of the nose cowling a silver color to represent the new metalwork. I also dabbed small amounts of the base color *over* the decal stripes around the edges to simulate peeling red paint. I then added ink to the panel grooves as on the other X-wing.

Before starting with the airbrush, I masked the cockpit windows and a couple of panels that I wanted to look new, and removed the R2D2 unit. I did not weather the R2D2 unit on either X-wing model, because leaving it shiny points up the fact that it is a drop-in part of the craft, and reminds the knowledgeable viewer of the details of the movie plot.

The colors I used for airbrush weathering were Pactra tinting black, Pactra white, and Floquil roof brown (very little) mixed in various combinations as I went along. Mix them in a ratio of approximately 1 part paint to 1 part thinner.

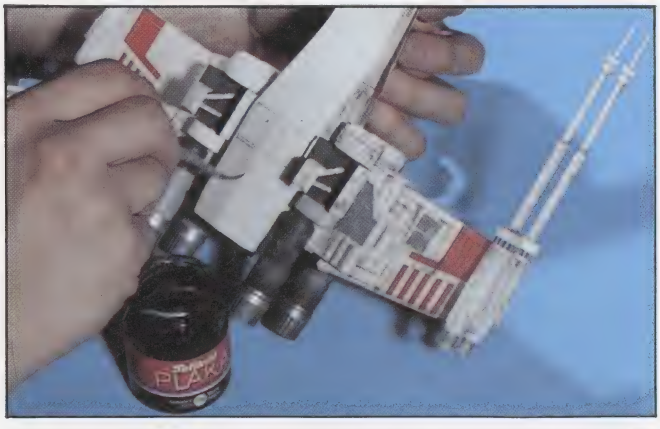
Adjust the paint feed and air supply on your airbrush to make fine — about $^{3}/_{64}$" wide — lines, and leave them at this setting. Apply paint to the model in much the same manner as the chalk on the earlier version, always streaking the color toward the rear and allowing it to tail off. In some areas I just shot short bursts of paint onto the model. With the airbrush aimed toward the rear, use a lighter weathering treatment on the insides of the wings; these portions of the craft would not normally be exposed in atmospheric flight.

After I was satisfied with the basic weathering treatment, I went over the model and added a few highlights with pastel powder, especially around the engine nacelles. These small touches don't require clear fixative spray unless the model will be handled frequently.

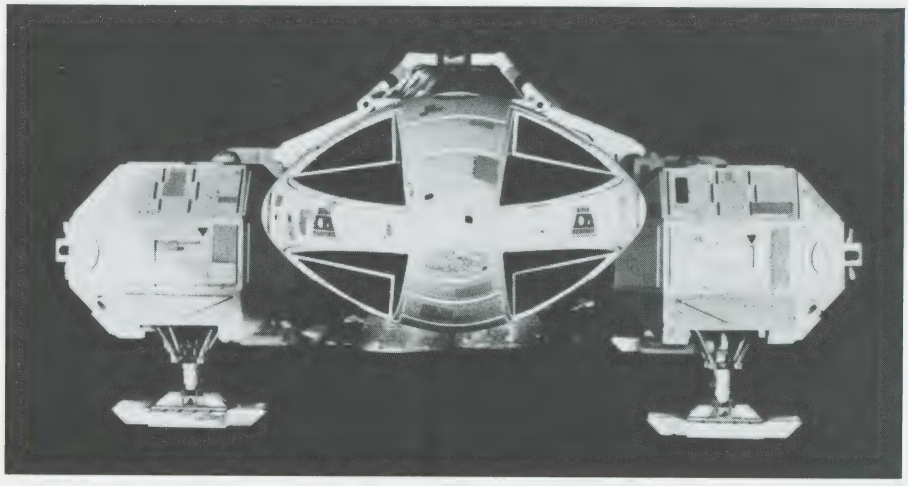
More notes — The poorest moldings in the MPC X-wing kit are the pilot seat, the pilot, and the little R2D2 droid. I improved the seats on both models by adding rounded cushions made from $^{1}/_{16}$" styrene sheet. Although my model with the gear down excludes the pilot, the figure in the attack-configured craft is a jet fighter pilot from a Tamiya 1/48-scale A-10 kit. I used standard military-miniature painting techniques to highlight and shade the figure to bring out the detail.

To rework the R2D2 unit, first sand away all the raised detail lines on the dome-shaped upper portion; fill any bad joint lines or mismatches with putty; and wet-sand to a smooth, regular hemisphere. You need not bother with the bottom portion of the unit, since it will not show on the finished model. Add a new ring of .004" sheet plastic at the point where the rounded part of the droid joins the cylindrical portion, and then dress up the dome with rectangular and square bits of sheet plastic and small slices of stretched sprue. I finished by airbrushing the unit silver. The five metallic blue segments on the dome were painted by hand. As I mentioned before, the R2D2 units are purposely not weathered.

My models show but two of the myriad variations possible on this attractive fighter. Here are a few more suggestions: an open canopy with a truly superdetailed cockpit interior, a battle-damaged version with evidence of laser hits on the engine nacelle and the R2D2 (as in the movie), or even a diorama crash scene. The rest is up to you.



Plaka ink was used to accentuate panel lines; chalks were used for weathering. Note several shades of gray paint on engines.



Venerable vehicles of Space: 1999...

THE EAGLES

CHRIS TIETZ/GEORGE ELRICK

SEPTEMBER 13, 1999: Moonbase Alpha is preparing for a deep-space probe launch and Commander John Koening is sent from Earth to spearhead the mission. Upon arrival at Alpha, he finds that several astronauts have died from what Dr. Helena Russell, head of Alpha's medical department, diagnoses as radiation illness: radiation suspected of emanating from a nuclear waste site on the moon's far side. (Moonbase Alpha, a thriving scientific community of over 300 men and women, also functions as guardian of Earth's nuclear waste deposits.)

After a painstaking investigation of the area, no radiation is detected. It's at this time that Professor Bergman discovers the leakage to be, not radiation, but a deadly magnetic buildup of tremendous energy with a horrifying potential if allowed to continue.

Eagle spacecraft (Alpha's mainstay transport vehicles) are instantly dispatched to the waste disposal site, equipped with winches and magnetic grabbers. Their task is to quickly hoist canisters containing nuclear waste out of the vast storage bins and disperse them over broad acreage to sidestep irreversible chain reactions. Their frantic efforts to outwit catastrophe are too late. The nuclear waste explodes in a thunderous drum roll of chain reactions that obliterate the Eagles at the site and much of the moon's surface. So stupendous is the force behind the explosions, the moon is ripped out of the Earth's protective orbit and hurled deep into uncharted space.

Thus the opening episode, "Breakaway," launches *Space: 1999* (and the moon) on a two-year television journey across the heavens. The kick-off sequence also firmly establishes the Eagle spacecraft as *Space: 1999*'s trademark. Once the workhorse of Moonbase Alpha, generally taken for granted, the odd-looking Eagle is now the most critical piece of hardware necessary for mobility and survival. In fact, it's the *only* mechanism by means of which the men and women of Alpha can eventually leave their confining, artificial environment. Unwilling passengers on a runaway satellite, destined never to set foot on Earth again, Alphans must be ready to defend themselves against threatening environments. They must also nimbly seize any opportunity to flee their prison for any habitable planetary system the moonbase may pass through in its cometlike trajectory. When the appropriate time for evacuation to a new world *does* arrive (code-named "Operation Exodus"), every available Eagle — loaded to capacity with personnel and supplies — will be used to leave the moon.

Until that longed-for eventuality, the Eagle remains the standard transport vehicle for all of Alpha's homebase maintenance duties and extra-lunar investigations. It's employed to investigate new phenomena as well as gather minerals for the colony's needed-for-survival recycling plants. Each craft, originally designed for short-range jaunts between the Earth and its sterile companion and for various duties in and around the moonbase, was constructed on that satellite, using materials either manufactured there or shipped from the Earth. Strikingly grasshopperlike in appearance and squatting close to the ground when not in flight, the Eagle is capable of atmospheric entrance to and exit from planets, with versatile landing capability, whatever the terrain.

Both photos, courtesy ITC Entertainment

Basically, all Eagles are the same: 76 feet long, utilizing a tubular frame to connect four nuclear fusion rockets to a command module at the bow. Though not designed for warfare, each has a laser gun in addition to an arsenal of space-to-space missiles. Each also carries sufficient fuel for 48 flight hours. Built-in artificial-gravity force fields enable any Eagle to accelerate to 15 per cent lightspeed. This acceleration, coupled with the fuel reserves, imparts a maximum range of several light-days. Inset windows, such as those of the Gemini capsule of the 1960's, are part-and-parcel of the command module's front. This module is ejectable as a unit from the rest of the ship. It's usually manned by a pilot and copilot, but can be maneuvered by a single operator. Drone or robot Eagles, containing no onboard personnel, are remote-controlled from a slave station at Moonbase Alpha's Command Center. In an emergency, should onboard pilot personnel be incapacitated, the same slave station takes over. (Note: To provide better protection, the Command Center was moved — during the show's second season — from a perch-top location to an underground fortress position.)

Examining the configuration from back to front, a small utility compartment is situated in front of the main-thrust engines. This contains various engineering systems plus the nuclear-generator power package. Another compartment, situated behind the command module, permits access to any of the midship service pods elaborated on in the following paragraph. Under both compartments are two of the four chemically fueled landing rockets. Four cubically shaped sub-pods, attached to the compartments' port and starboard sides, are equipped with hydraulic landing gear, fuel tanks, and maneuvering rockets.

Between the forward and aft compartments, a space is reserved for one of many interchangeable service pods, which measure 27 feet in length, 15 feet in width, and 9 feet in height. Each service pod is equipped with four chemically fueled landing rockets plus retractable support legs, so the pod can be transported to any location by an Eagle craft and released to operate independently. Once a service pod is detached, however, ready access is cut off between the command module and the aft engine compartment. If a need arises to enter the engine compartment, it's necessary to suit up and take a cumbersome space walk the length of the absent service pod.

Obviously, each spacecraft's function is determined by the type of service pod it carries in its metal belly.

The transporter Eagle ——— This configuration, utilizing a transport pod, is designed to comfortably carry eight passengers complete with stewardess. Under emergency conditions, it can carry 12 passengers. The transporter provides basic transportation when no special equipment or caution is required.

The reconnaissance Eagle ——— The recon pod, which outwardly resembles the transport pod, houses sensor devices and data-gathering equipment for planetary and space exploration missions, plus an onboard computer that operates independently or in link with Alpha's Command Center computer.

The freighter Eagle ——— Freighter pods are employed to transport equipment and supplies wherever needed, and to collect foreign elements and samples for evaluation at Alpha. These pods have an additional capability: They can directly process and refine crude minerals found on a planet's surface, eliminating the need to haul bulky ores back to the moonbase.

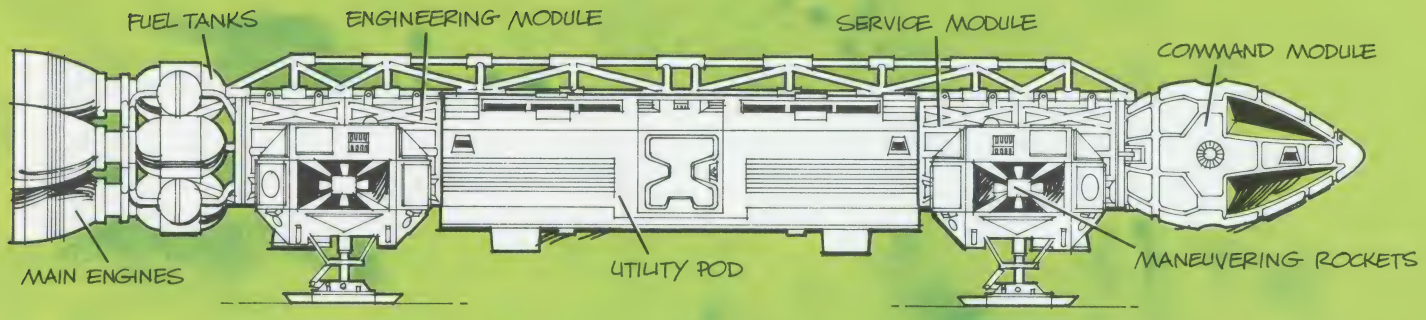
The rescue Eagle ——— The rescue pod is a mobile hospital equipped for medical emergencies and the transport of sick or injured personnel to Alpha's fully staffed, elaborately supplied medical department. Trained personnel aboard, with sophisticated patient-monitor units, can handle anything from simple injuries to major field surgery.

In addition to these standard service pods, custom-built pods can be prepared for unusual situations in which normal pods would be useless. The Eagle can also be fitted with various utility platforms in place of the service pod, such as the winch set-up employed at the nuclear waste site. Another accessory each Eagle can accommodate is a special booster pack attached to its frame to add extra thrust and range, first introduced in the second-season opener — "Metamorph."

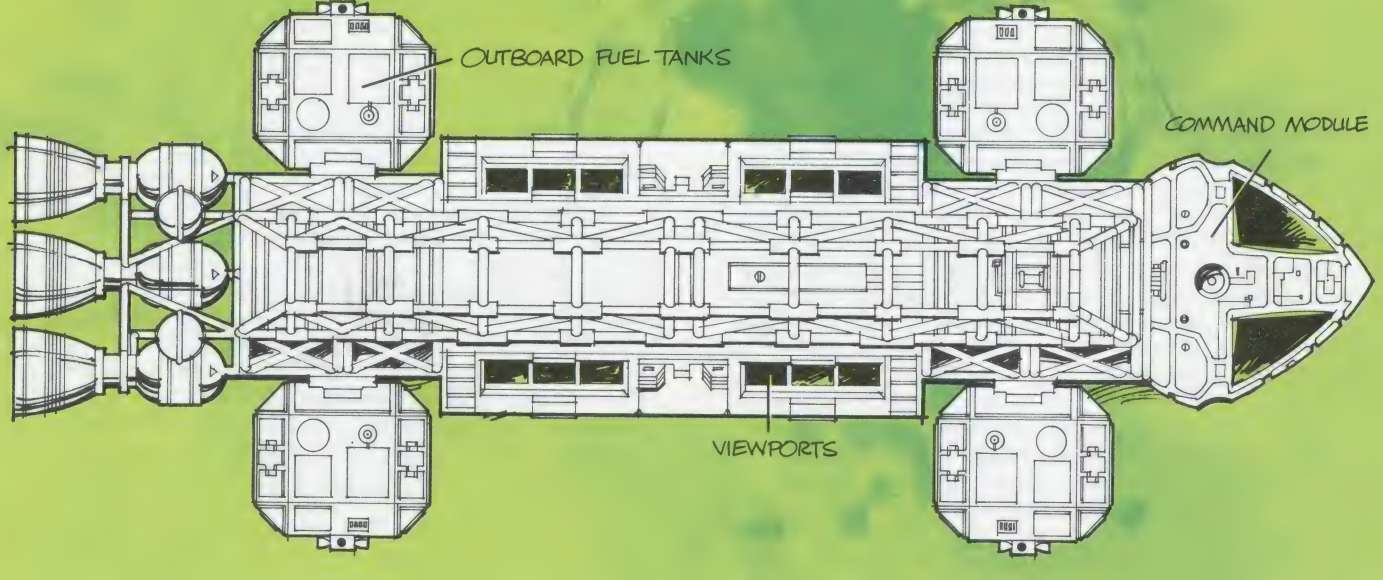
Alpha has four Eagle landing pads within its extensive perimeter which are linked by underground travel tubes.

Brian Johnson is responsible for the design and filming of the Eagles and all other miniatures used in *Space: 1999.* His film credits include *2001: A Space Odyssey, Thunderbirds,* and *UFO.* It's interesting that *Thunderbirds* featured a gargantuan aircraft, *Thunderbird 2,* which had interchangeable service pods, as do the Eagles.

Space: 1999 utilized four different sizes of Eagle miniatures for filming: 44 inches in length (beautifully detailed), 22 inches, 11 inches, and 5½ inches. Constituents of all models were plaster, plexiglass, and molded copper piping. The largest Eagle model was used for close-ups and was equipped with gas jets on its underside to stir up dust when landing and taking off.


FUEL TANKS
ENGINEERING MODULE
SERVICE MODULE
COMMAND MODULE
MAIN ENGINES
UTILITY POD
MANEUVERING ROCKETS

LANDING PADS


OUTBOARD FUEL TANKS
COMMAND MODULE
VIEWPORTS

Shadows brighten the Eagle

KIT: *Space: 1999* Eagle 1 Transporter
MANUFACTURER: MPC, U.S.A., Kit No. 1-1901
SCALE: Unstated; approximately 1/76
DIMENSIONS: Length — 12″; Width — 4 11/16″; Height — 2⅛″.

Don Klein

THE EAGLE typifies the challenge facing the modelers of many of today's spaceship models. Namely, the spaceships are painted white or appear white on TV and movie screens, but a straightforward rendition of the model in white leaves it looking toylike.

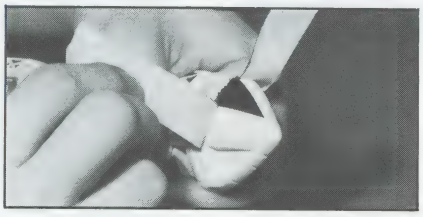
Heavy weathering averted this problem with the X-wing fighter. Judicious use of grays on panels and details also overcame this potential problem with the basic off-white I gave my model of the TIE fighter.

For the Eagle, I followed a course of more moderate weathering, although the process was fraught with trial and error.

The Eagle kit goes together quickly due to parts fitting well. Filing was needed to remove the seam line after the command module halves were cemented together. More filing and scraping was done on the lattice-frame superstructure.

Before painting, I built the kit into several subassemblies. The command module, forward compartment, superstructure, and rear compartment (but not the rocket nozzles) were cemented together. The main utility pod was also cemented; and, as with the command module and superstructure, it was sanded along the seam lines. The four sub-pods were assembled but not attached.

The rocket nozzles were airbrushed with Testors silver. The sub-assemblies were airbrushed white. I tried several brands of enamels: on one occasion, the white turned greenish; on another occasion, the finish turned grainy. I finally settled on Humbrol underside white.



I masked around the command module's inset windows, then painted the area black with a brush. As soon as the paint application was finished, I peeled back the masking tape.

Some additional work on the command module turned into one of the major modifications I made on the model. There is a small steering rocket on each side of the command module. Using a Dremel ball cutter, I bored out the cone-shaped depression; after filling the edges with Green Putty (cut with Testors liquid cement), I wet-sanded to a dish shape. The addition of a domed piece of sprue simulated a retrorocket dome. The modification was sprayed with Testors silver.

On the television models, the forward and aft compartments are surrounded by the pipe framework of the superstructure; but on the MPC model, the outlines of the framework are merely molded over the compartments. I wanted to give this area the three-dimensional effect it required. One way to accomplish this, of course, would be to cut away the segments between the framework that represent the compartments. This would expose and create actual framework in place. Then, you would have to fabricate compartment sides out of sheet plastic and insert them behind the framework.

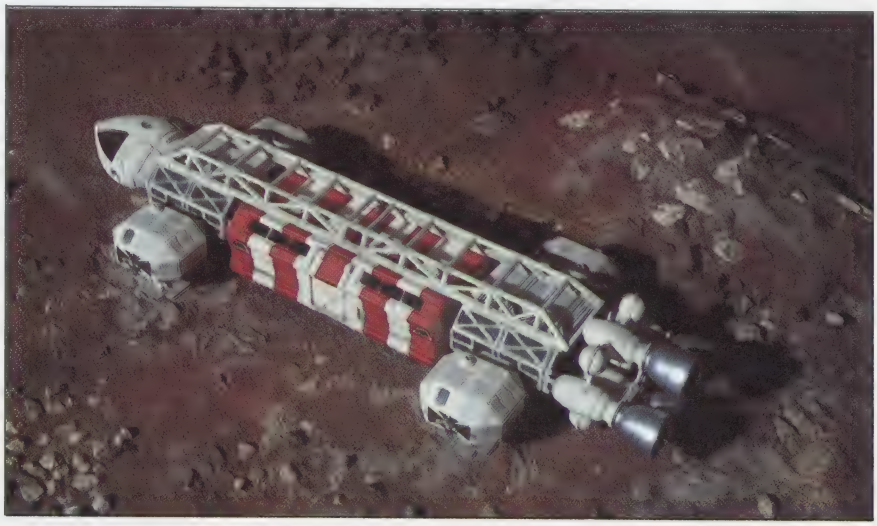
However, I wanted to achieve a three-dimensional effect without modifying the kit. After the white paint had dried, I brushed a flat black paint in and around the framework. This didn't look satisfactory. Next, I tried Plaka ink — it cracked off. Finally, I settled on black Grumbacher pastel chalks applied with a 000 brush. I blended the pastels into the framework, creating a shadow effect and making a transition to the deeper black areas. I used white pastels to accentuate the framework in a couple places where I had brushed too much black.

The weathering was also done in pastels — light gray, dark gray, and dark brown. I weathered the model to a consistent overall degree, but I can see the opportunity to weather according to a particular situation. For example, the underside could be dusted with browns to simulate the dust encountered when landing and taking off from a brown planet.

Two more things were beyond standard kit construction: I built two pods and modified the small thruster rockets.

The first pod I built was the standard passenger or utility pod, which could also pass for a reconnaissance pod or freight pod — they all look similar on the outside. This pod was painted Humbrol underside white with a few drops of Pactra aero blue added. The second pod was a rescue pod. I painted this one underside white with Pactra brick red stripes. Both pods — especially the undersides — were brushed with dark pastels.

The thruster or maneuvering rockets, which are mounted on the side of each of the four cube-pods, were drilled out with a pin vise. I sprayed them with Spray 'N' Plate silver and added them after the rest of the Eagle was finished. As a final fixative coating over the model, I used Spray 'N' Plate final finish.



Working together for a new era in Space...

ORBITER

JAMES E. OBERG

THE SPACE SHUTTLE PROJECT created the world's first true spaceship, a vessel designed to conduct the commerce of the stars. The winged spaceship is known as the Orbiter, and together with the giant External Fuel Tank and two Solid Rocket Boosters, it comprises the total Space Shuttle configuration.

In the past, space capsules splashed down at sea or thumped down on the endless prairies of Soviet Central Asia. Now a new technique has been pioneered: gliding down from earth orbit — from heights and speeds never before dreamed of for winged craft — to a smooth landing on a long runway.

The Orbiter spread its fledgling wings in the summer of 1977, during a series of flight and landing tests conducted at Edwards Air Force Base, in the Mohave Desert of California. Following eight captive flights, in which the Orbiter remained attached to a Boeing 747 airliner converted to a Shuttle Carrier Aircraft, came five free flights, in which the Orbiter separated from the 747 at altitude and was piloted to approach and landing by astronaut crews. The way was cleared for space missions!

Let's take a close look at this spaceship. The sleek, streamlined Orbiter consists of three main parts: the crew cabin, the payload bay, and the engine section. Delta wings and a lightweight tricycle landing-gear assembly complete the package. The outside is lined with insulating tiles (giving rise to the nickname, "the brick airplane"), but during the 1977 drop tests these tiles were only dummies, as were the giant main engines in the rear.

The crew compartment consists of three decks: flight deck, mid deck, and lower deck. Four crew couches occupy the flight deck (during the first drop tests as well as first orbital tests, just a commander and pilot occupied the flight deck, sitting in bulky ejection seats that later were removed). Additional crew couches — up to six — are installed on the mid deck.

The pilot's view from the flight deck approximates that of a pilot of a commercial airliner. Many of the instruments are similar. Many specialized instruments have, of course, been added, particularly the television display screens and keyboards for operation of the Orbiter's flight computers. Although the crew has a very wide-angle view out of the windows, the high descent rate of the Orbiter on landing means that, first, the astronauts are often looking at a point on the ground in front of the runway, and second, during the final "nose-up flare" prior to touchdown, they cannot see the runway over the nose of the Orbiter. So the instruments are vital.

Continued on page 48

Orbiter 101 and 747 NASA 905 just before and after separation on first tailcone off test.

Both photos, NASA

747

HAROLD A. EDMONSON

FOR TWO DECADES the Space Age replay of cylindrical Jupiter, Atlas, Titan, and Saturn rockets blasting vertically toward the black depths of space behind all-consuming streams of orange flame seemed as far removed from the world of conventional aviation as a sparrow sitting on the same runway with a 707.

Suddenly, with the advent of the Space Shuttle Orbiter, the Space Age has seemingly merged with the Aviation Age. The Orbiter looks more like an airplane than a spaceship. There's good reason of course — it has to be an airplane (or at least a glider) for its return to earth to be reused as a spaceship. Yes, the Orbiter has given true significance to the term "aerospace." And the term achieves even more significance when the Orbiter is attached to a converted 747 Shuttle Carrier Aircraft (SCA).

The 747 is being used to carry Orbiters piggyback style from their assembly site at Palmdale, Ca., to the launching sites at Kennedy Space Center, Fla., and Vandenburg Air Force Base, Ca. In addition to ferrying the Orbiter back to the launching sites following the first orbital test landings at Edwards Air Force Base, Ca., the 747 is available to ferry Orbiters back to the launching sites after any emergency recoveries that may take place away from those sites, such as at Hickam Field, Ha.

The first 747-Orbiter flights took place in 1977, when the test vehicle *Enterprise* was lifted above the NASA/Dryden Flight Research Center at Edwards Air Force Base for a series of airworthiness tests followed by drop tests in which the Orbiter glided down to a landing.

The 747-Orbiter combination may be the most awe-inspiring sight in the American sky (with the exception of an actual rocket launching), but there are still some superlatives which are not the property of NASA's dynamic duo.

No, the piggyback operation is not the first mating of aircraft. In a notable experiment in 1938, a small four-engine pontoon-equipped seaplane transport built by Short in England was positioned on top a Short Empire flying boat. The theory was that range and payload could be increased if the larger plane carried the smaller one to cruising altitude, where it would be released with full fuel tanks. Test flights to the U. S. and South Africa were made. During World War II, Germany mounted Focke-Wulf intercepters on top of Ju 88's for air launches against American bomber fleets.

No, NASA's two together do not represent the heaviest payload or total weight supported by wings. A world record for maximum mass lifted to 2000 meters (6,562 feet) was set on November 1, 1976, by a Boeing 747-200B

Continued on page 52

Rockwell International

Numerous ground tests of the mated 747 and Orbiter preceded flight tests. Ground testing showed that the 747's landing gear and braking systems were adequate and yielded important data on the forces acting upon the coupled aircraft.

These Orbital Maneuvering System engines are located in pods to the left and right of the Orbiter's tail structure. Additional rockets, called the Reaction Control System, are located in the OMS pods and in the Orbiter's nose section. These small rockets provide attitude control; *i.e.,* they change the pointing of the spaceship as it falls freely through the vacuum of space.

One of the most important, if little known, units on the Space Shuttle is the Auxiliary Propulsion Unit, which uses hydrazine fuel to generate hydraulic pressure with which to move the Orbiter's aerosurfaces during launch and landing. Conventional jet aircraft bleed pressure off their jet engines to provide this power, but a special unit must be installed on the Orbiter.

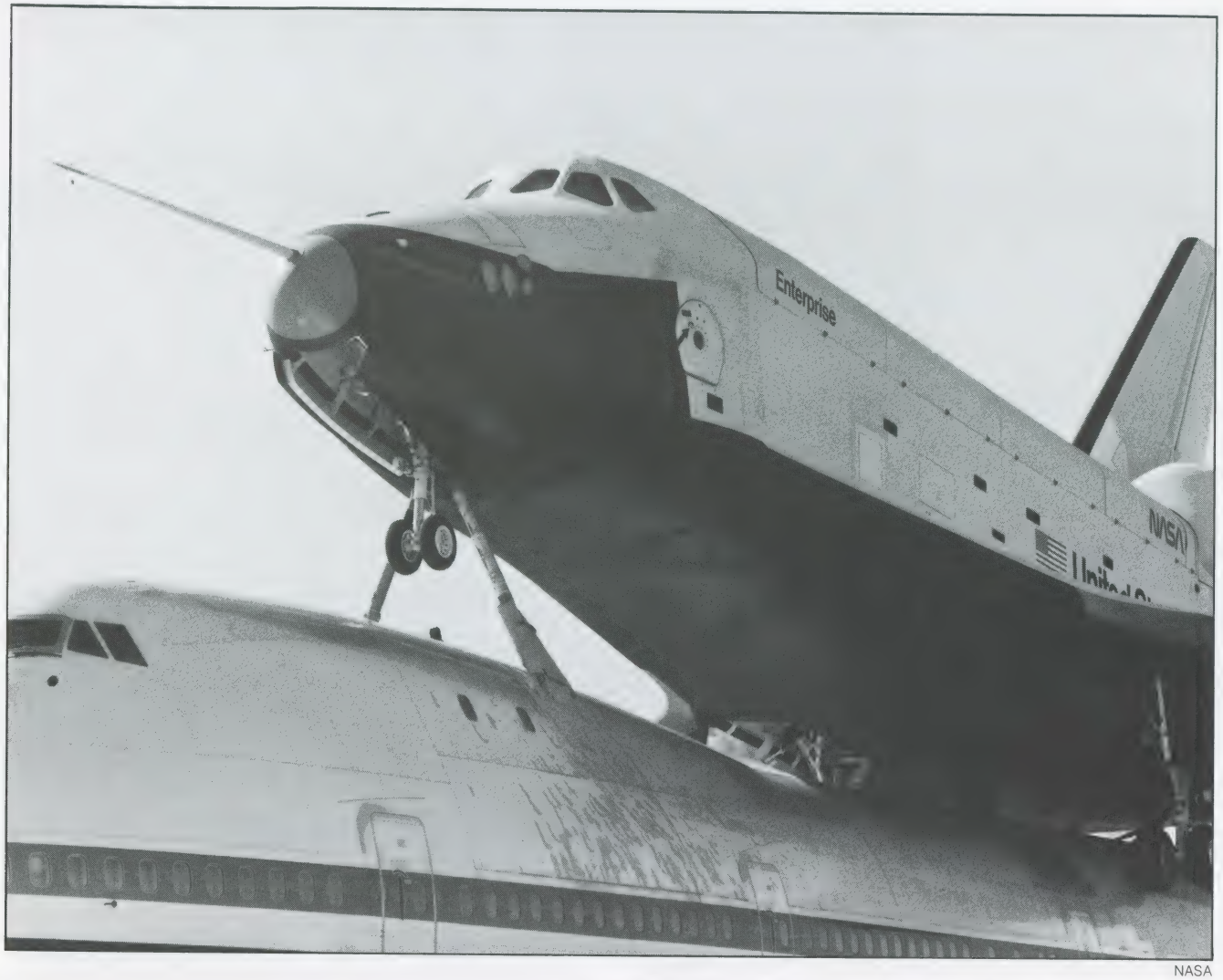
There are six movable aerosurfaces: an inboard and outboard elevon on each wing, a rudder, and a new type of surface called the "body flap," mounted below the main engines like a boat tail. The inboard and outboard elevons normally act together on each wing. The rudder is split and can splay outwards to port and starboard to act as an airbrake, or both halves can turn together to act as an ordinary rudder.

The wings, indeed, may seem like they are for little more than show, since a great deal of the spaceship's aerodynamic lift is derived from the shape of the body (the "lifting body" technique) and the high angles of attack (the nose is pitched very high relative to the air stream) of a normal landing. The sink rate during landing is terrifyingly high, and the glideslope angle is downright scary — as great as 40 degrees (conventional aircraft land with a glideslope of a few degrees at most). The return from space is made with all propellant exhausted, so it's a true glide — with only one pass at the runway.

That's why the drop tests in 1977 were so important. Were the aerodynamic characteristics of the Orbiter computed correctly? Did the revolutionary fly-by-wire computer control system work? Could the ultra-lightweight hydraulic and landing gear systems handle the loads? Did the crew training procedures faithfully reproduce the actual handling characteristics of the Orbiter?

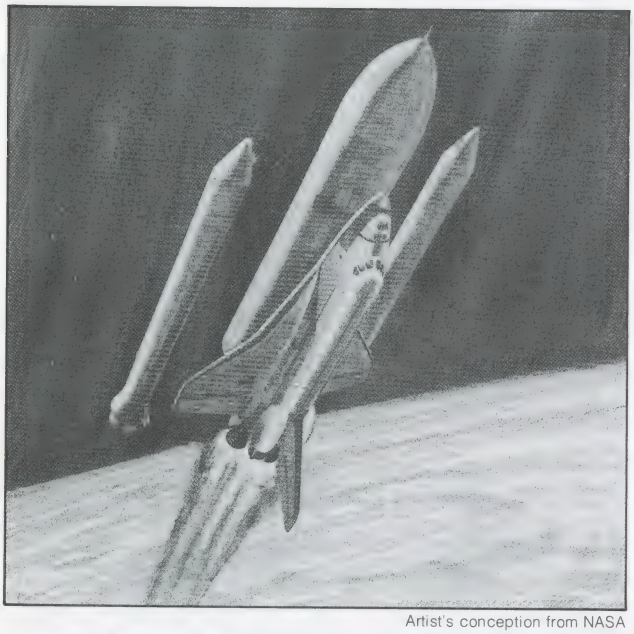
There was no way to find out but to try. So, with Commander Fred Haise and Pilot Gordon Fullerton at the controls on August 12, 1977, the Orbiter *Enterprise* (No. 101, first off the assembly line) lifted off the back of the nose-down 747 mother ship at 24,100 feet and began a 5-minute 21-second glide to the dry lake bed runway below.

The answer was "yes!" The Orbiter flew as it had been expected. The onboard computer control system



NASA

Gear down, Enterprise rested atop 747 at conclusion of the series of captive-active flights that served as dress rehearsals for the free flight tests.



Artist's conception from NASA

Reusable Solid Rocker Boosters are jettisoned and returned to earth by parachute. External fuel tank is expendable.

worked. The new flight systems all functioned adequately. The actual flight experiences were very similar to the ground simulations, so future crews could rely on simulations with confidence.

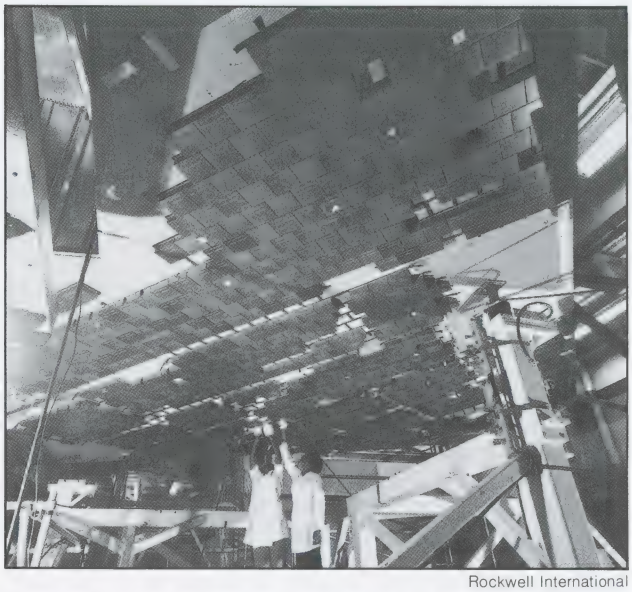
In this and four subsequent 1977 flights, the *Enterprise* cleared the way for space missions for the next Orbiter off the assembly line, No. 102, as well as for three more Orbiters slated to join the program later.

The *Enterprise* next was sent to Huntsville, Ala., where Saturn booster rockets were built, for special vibration tests. It was bolted to the rocket engines and fuel tank, then shaken and stressed and strained to simulate an actual liftoff. Concluding these tests, vehicle No. 101 was cannibalized along with structural elements from other stress test vehicles, to be reborn for space flight as the hybrid vehicle called No. 99.

As such, the *Enterprise* could achieve the spaceship status a hundred thousand *Star Trek* fans undoubtedly had anticipated for it when they besieged Washington with letters suggesting that NASA's first Orbiter be named after the famous spaceship of the television series. The constituents succeeded and No. 101 became

NASA

Orbiter's fuselage configuration and tail-down descent posture limit visibility during glide; after touchdown, steep nose-down attitude allows good view of runway.



Rockwell International

Orbiter 101 wore dummies; later ships are protected to 2300° F. by reusable tiles, here being bonded to Orbiter 102.

the *Enterprise,* but not a fully potent *Enterprise*. The engines were only dummies, because the real engines were neither ready nor needed to conduct landing tests. The exterior tiles were also dummies, not made of the heat-resistant materials that are required for re-entry by the true Orbiters. No. 101 also tested the large tail cone that gives better aerodynamic stability during 747 ferry runs.

FROM ORIGIN TO ORBIT

After the Saturn and Apollo programs proved the potential of space flights and space research, NASA and the Government sought to define a follow-on program to continue manned space exploration. The key to a successful and economical program would be the employment of reusable components, in contrast to the "throwaway" philosophy of Saturn-Apollo. In 1972, NASA selected Rockwell International's Space Division as the major contractor. Numerous other companies became subcontractors of Space Shuttle components.

The first Orbiter vehicle, the *Enterprise,* was rolled out of the final assembly facilities at Palmdale, Ca., on Sept. 17, 1976. NASA originally wanted eight Orbiter vehicles, but the administration of Pres. Jimmy Carter finally approved only four vehicles, with a fifth to be constructed from parts of the *Enterprise* and the stress test vehicles.

Many types of launch vehicles and rocket combinations were studied, but the configuration ultimately approved consists of two Solid Rocket Boosters (SRB) mounted to a large External Tank (ET) to which the Orbiter Vehicle (OV) is also attached. Lift-off is accomplished through the thrust of the two Solid Rocket Boosters and the three rocket engines on the Orbiter, which are supplied fuel from the External Tank.

After launch the Solid Rocket Boosters separate and are returned to the earth by parachute, where an ocean recovery is made for reuse. The External Tank is separated just before orbit insertion and is not reusable. In fact, it burns up during re-entry into the atmosphere.

After completing its scientific mission, the Orbiter returns to earth. Under computer control, the Orbiter turns tail forward for a few minutes and fires the small Orbital Maneuvering Engines, slowing its speed by less than one per cent. But that's enough to lower the orbit by a hundred miles, to deep within the atmosphere. Air drag does the rest.

The spaceship falls almost halfway around the world, coming lower and lower and faster and faster as it picks up speed on the downhill coast. Gradually, the thin air drags at the 5-miles-per-second spaceship.

As deceleration forces build, the astronauts are pressed *downwards* toward their feet, unlike the pressure *backwards* during launch. The Orbiter now rides belly forward, facing the coming flames like a surfboarder. The tail surfaces are still in a vacuum, but the reaction rockets in the nose and the wing elevons can be used to maintain control. Strange hypersonic aerodynamic control effects come and go, challenging the flight computer and the pilots.

The Orbiter is protected from the temperatures of re-entry by the array of tiles, thicker at the hottest points, and reinforced with a super-hard material called "carbon-carbon" at the leading edges of the wings and nose. The black tiles are the high-temperature insulation, while the white tiles are the low-temperature insulation. The tiles do not burn away upon re-entry, but are designed to last the mission life of the Orbiter (although they can be individually replaced).

The Orbiter enters the atmosphere not in a straight line but swooping to the left and right. This crossrange capability allows it to come to earth hundreds of miles to the right or left of its flight path, and reduce speed in the process of maneuvering to its landing path.

Along the ground thousands of feet below, a far-off thunder is heard, heralding the spaceship's arrival with sonic booms. The astronauts aim for the end of the distant runway, conserving enough — but not too much — momentum to just reach their touchdown point.

The final few minutes of flight proceed like those of the 1977 drop tests. Escort jets fly alongside the Orbiter. Landing gear is deployed. The Orbiter touches down at speeds between 180 and 200 mph. The mission is just about over . . . but in as little as two weeks the Orbiter can be ready for another launch.

Removable tip fins on horizontal stabilizer, removable and adjustable fore and aft strut assemblies, new panels, and remnants of AA livery distinguish 747 NASA 905.

Boeing

Continued from page 47

which took off during noise-level certification trials with a grossweight of 840,500 pounds. Freight versions of the 747 carry heavier loads — though internally — than the 150,000-pound weight of the Orbiter. Lockheed's C5A of the Military Air Transport Service can carry a 58-ton M60A1 tank (vs. the 75-ton Orbiter) and cargo totaling 265,000 pounds.

Even the selection of a 747 ferry system was not at first the obvious one. NASA, prime contractor Rockwell International, and various consultants considered several possibilities for moving the Orbiter through the atmosphere. The original concept of the Orbiter included an air-breathing propulsion system that would be deployed from the aft section of the cargo bay to permit a powered-flight return to the runway. When the decision was reached to return the Orbiter unpowered through the atmosphere, a proposal was studied that would place jet engines under the wings for atmospheric testing and ferry flights.

In February 1974 the decision was made to delete the air-breathing propulsion system in its entirety and utilize a carrier aircraft for ferry flights and atmospheric flight testing. Thus the weight and complexity represented by the fuel tanks, plumbing, valves, wiring, and controls of an air-breathing system could be avoided. The Boeing 747 and Lockheed C5A (one idea called for a dual-bodied C5A to be built with a middle wing from which the Orbiter could be hung) were selected as the candidate carrier aircraft.

At the time, a number of 747's were in storage on account of the economic slump. One of these, American Airlines N9668, had been the 86th plane off the 747 production line. From its delivery on October 29, 1970, it had accumulated 8,999 flight hours on 2,985 flights, primarily between New York and Los Angeles. NASA purchased the airplane from AA on July 18, 1974, for 15.6 million dollars. Design work on transforming the passenger-carrying jetliner into a Shuttle Carrier Aircraft had already begun that April.

Through NASA's prime Orbiter contractor, Rockwell International, a contract for the modification was awarded to Boeing. Hours of design work and testing (even wind-tunnel testing on models) followed, with the actual modifications installed by a Boeing Aerospace Company-Boeing Commercial Airplane team between August 2, 1976, and January 14, 1977, when the aircraft was turned over to Rockwell and NASA for its flight from Paine Field, Everett, Wa., to Edwards Air Force Base. Cost of the engineering work and one-time modifications: 30 million dollars (a new 747 now costs upward of 50 million dollars).

For engineering purposes, the modifications were divided into two types: Type One, or permanent structural and system changes; and Type Two, or removable structures used only during transporter and approach-and-landing-test missions.

For those readers interested in modeling, however, the modifications could more appropriately be divided into those which are pertinent for modeling the 747 and those which are not.

CHANGES OF INTEREST TO MODELERS

Of the obvious, exterior modifications, the addition of two 10 x 20-foot horizontal stabilizer tip fins stands out the most. The tip fins were added because the normal airflow to the main vertical stabilizer is blocked when the

Orbiter is in position. The tip fins are manufactured from aluminum, with the exception of 15-inch end caps made of glass fiber. Because the fins do exert stress on other portions of the airplane, they are not permanent, but can be separated into two pieces and stored within the 747 for non-transporting flights.

To support each of the 900-pound fins, the horizontal stabilizers were reinforced along 30 per cent of their outboard span. A diagonal brace from the upper surface of the horizontal stabilizer to the fin also provides support.

The next most apparent modifications were the addition of three strut assemblies on top of the fuselage — one forward and two in adjacent positions to the aft — which directly support the Orbiter. Even these assemblies are removable and adjustable. In fact, the exact specifications of the forward assembly changed according to the mission.

For the approach-and-landing tests conducted at Edwards in 1977, the forward assembly was a bipod consisting of two tubes each 13 feet long, plus appropriate end fittings. This assembly had an adjustable drag strut on the aft side of each tube to support the bipod after the Orbiter was launched.

For ferry missions, the forward bipod consists of two tubes each 8.5 feet long. Drag struts are not used.

The configuration of the aft support assembly has been the same for the test and ferry missions. Each aft support assembly consists of a 4.5-foot-high vertical strut and a 12-foot-long drag strut angled forward. The aft right support also has a 4.8-foot-long side strut angled from the vertical strut to the top center of the fuselage. The aft left support has two small-diameter struts angling to the top center of the fuselage (these are actually "non-load-bearing dual adjustable side snubbers"). Panels or skirts appear on the outside of the side struts, and these are among the most noticeable features in photographs. Short braces extend from the skirts to the fuselage. The right vertical strut is fixed while the left strut is adjustable a fraction of an inch vertically and about 4 inches horizontally.

At the positions where the strut assemblies were added, the aluminum skin had to be removed, and was later replaced with new aluminum. Although most of the area involved was painted gray, some of the new panels were left exposed, creating a finish with different shades and tints from the overall finish. In fact, new paneling was added to both sides of the rear fuselage just above the window line, resulting in distinctive aluminum coloration patterns.

Also painted gray by Boeing were the vertical stabilizer and rudder, the tip fins, the fuselage tail cone, a small area where the fuselage's second deck tapers into the fuselage itself, and fuselage door outlines.

The original American Airlines' window line colors of red, white, and blue were left intact because to remove them simply would have been too expensive. The word "American" was removed from the sides of the fuselage, but the area under the letters had become oxidized (bleached by the sun). Boeing deoxidized the area but it did not come out the same as the surrounding area, leaving a "ghost" image of the word American which is visible when viewed from certain angles.

OTHER CHANGES

Many interior changes — although not of immediate concern to modelers — were made to the aircraft. Three bulkheads — one forward and two aft — were added to bear the load from the strut support assemblies. Frame strengthening and skin reinforcement were also performed at stress points.

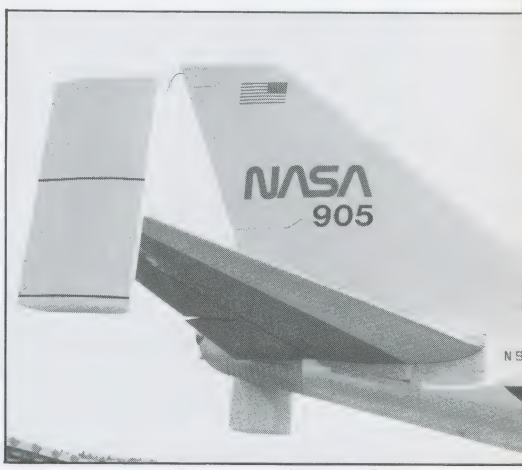
All passenger accommodations and unnecessary related structure were removed except for that which was required for the crew and a few passengers. Ballast tanks were added. Special instrumentation was installed for both air-launch tests and ferry runs.

Under a separate contract, Pratt & Whitney reworked and uprated the 747's original JT9D-7H 43,500-pound thrust engines to the JT9D-3A configuration with 46,950 pounds thrust. There is no external difference.

Another major part of the program was the construction of a tail cone to be attached over the Orbiter's main engines to reduce the turbulence around the tail of the 747. Although the tail cone was used in early drop tests, its main function is that of reducing the air turbulence during ferry runs. The typical ferry run is flown at 270-300 knots at a cruising altitude of about 18,000 feet. On long flights, intermediate refueling stops are made.

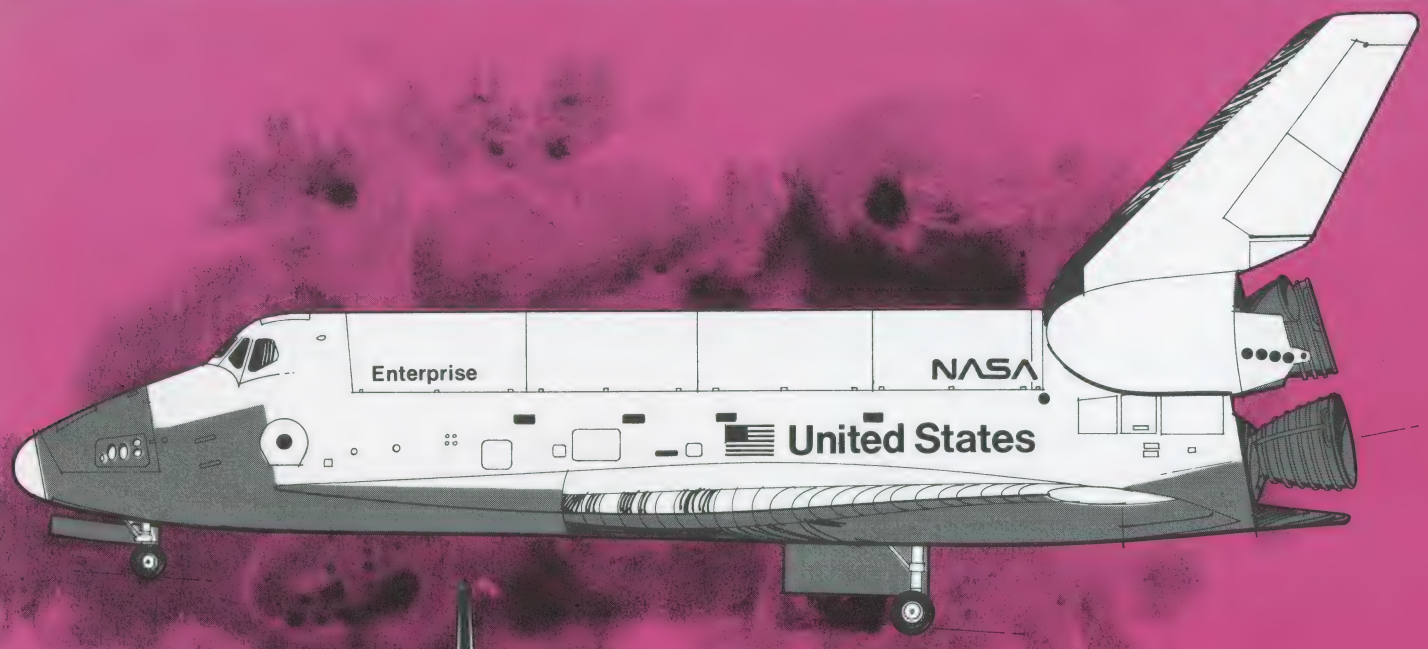
Forward strut assembly changed from mission to mission; it looked like this during 1977 tests at Edwards.

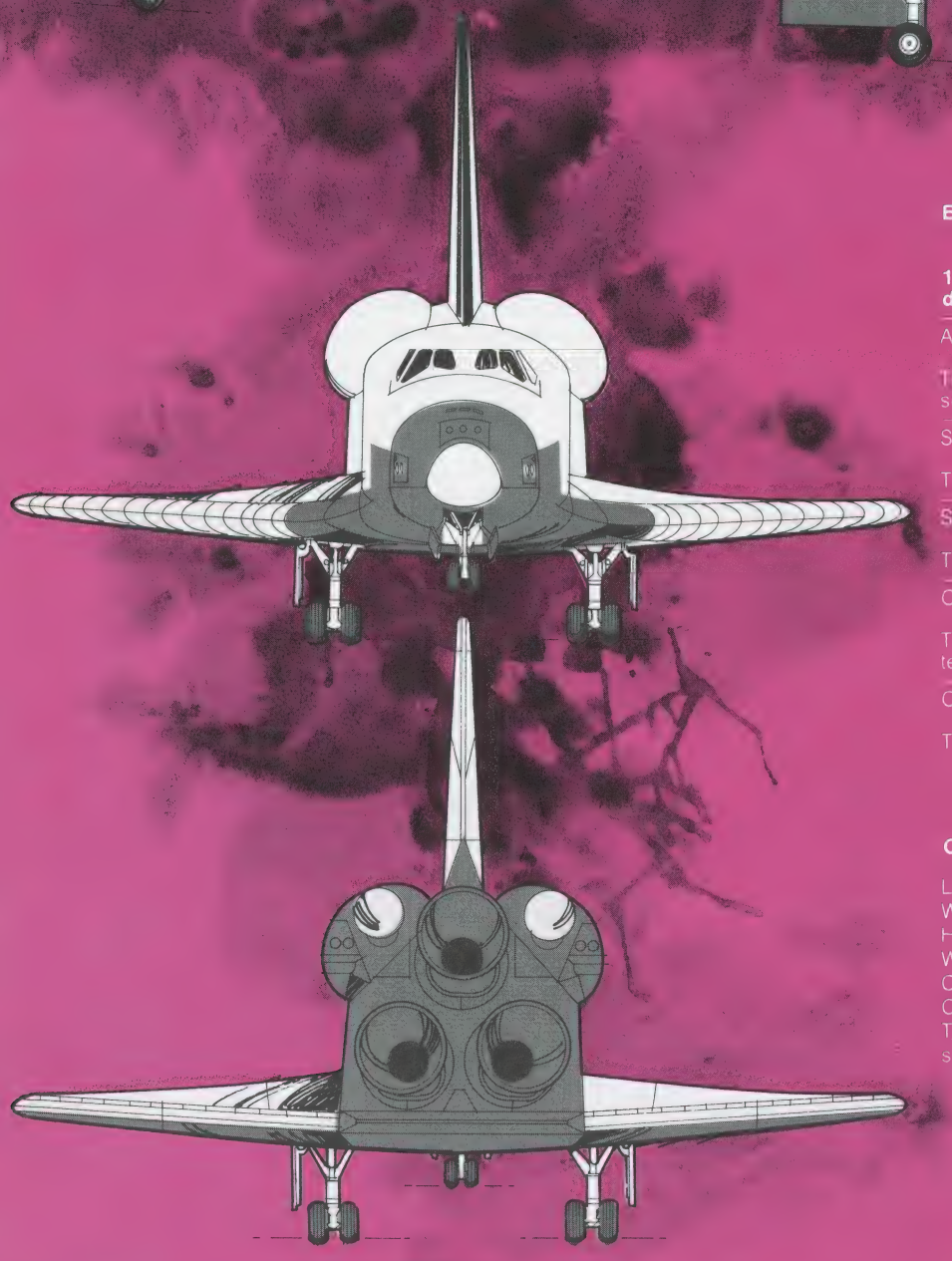
Aft strut assemblies changed less often, but were later covered by skirts on the outsides of the side struts.



All photos, Boeing

Tip fins are normally worn by 747 only when Orbiter is being transported; otherwise, they are stowed in fuselage.





ENTERPRISE 101 Manned Free Flight Tests

1977 dates	Free flight duration	Separation altitude	Crew-members	Tail-cone
Aug 12	5 min 21 sec	24,100 feet	Haise Fullerton	on
Test separation procedures and sub-sonic airworthiness.				
Sep 13	5 min 28 sec	26,000 feet	Engle Truly	on
Test airworthiness and flight control systems.				
Sep 23	5 min 34 sec	24,700 feet	Haise Fullerton	on
Test "Autoland" computer control system.				
Oct 12	2 min 34 sec	22,400 feet	Engle Truly	off
Test craft with tailcone removed; test steep descent.				
Oct 26	2 min 2 sec	19,900 feet	Haise Fullerton	off
Test landing on 15,000 foot runway.				

Orbiter Specifications

Length	184.2′
Wingspan	78.06′
Height	56.67′
Weight (with payload)	188,000 pounds
Cargo bay length	60′
Cargo bay width	15′
Thrust of each engine at sea level	375,000 pounds

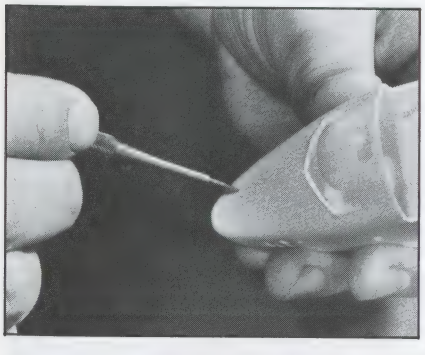
Modeling modifications give Orbiter lift

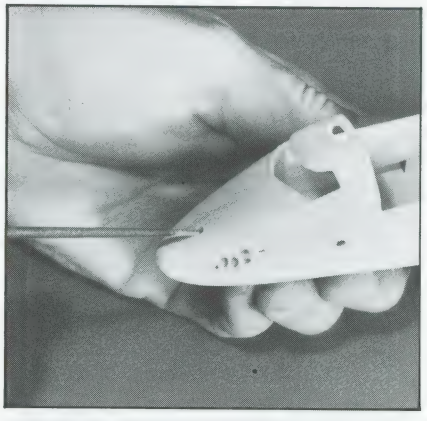
KIT: Space Shuttle and 747
MANUFACTURER: Revell, U.S.A., Kit No. H-177
SCALE: 1/144
DIMENSIONS: 747 — wingspan 16⅝″; overall length 19″; height (landing gear down) 5 7/16″. Shuttle — wingspan 6⅝″; overall length (less nose probe, tailcone on) 11 ¼″; overall height (landing gear up) 3¾″. Overall height of paired 747 and Shuttle 6 7/16″.

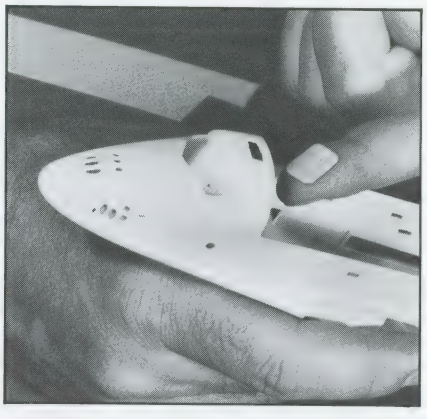
Al Jones

REVELL'S Orbiter is a straightforward kit that benefited from some basic modifications to make a more convincing replica of the prototype. I modified the kit by sealing closed the swinging shuttle-bay doors, by opening up windows and rocket ports, by filleting the wing-fuselage join line, by adding canopy window posts, and by simulating the heat-absorbing tiles that are such a distinctive feature of the Orbiter.

Before reinforcing the fuselage with a sheet styrene internal brace and sealing closed the bay doors to increase the model's structural integrity, I decided to open up the nose thruster holes which are represented in the kit only by a decal. **I located the proper placement of the holes with a scribing tool and used a drill bit in a pin vise to open them. I then used a large**

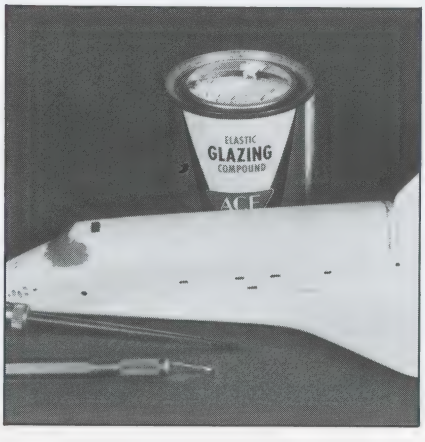






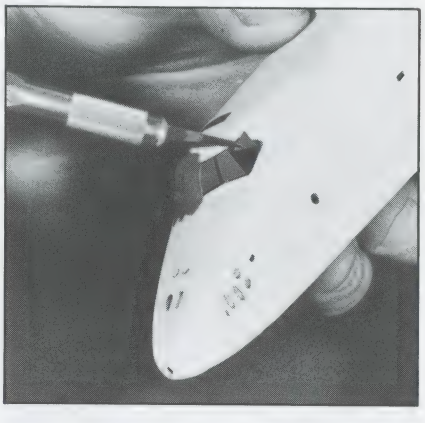
diameter drill bit to enlarge the holes to almost their finished size. Using a rattail needle file, I further enlarged the holes and brought them to their proper oblong shape. Finally, I cemented a small piece of sheet styrene backing behind the openings. Using the same techniques, but with a flat file, I opened up and backed the rectangular umbilical and vent doors on each side of the fuselage.

Upon assembling the wing, I discovered that the kit's wing-fuselage join line was too sharp. **In order to create a more realistic join line, I filleted the area with elastic glazing compound applied with a clean steel tool with the same tip radius**



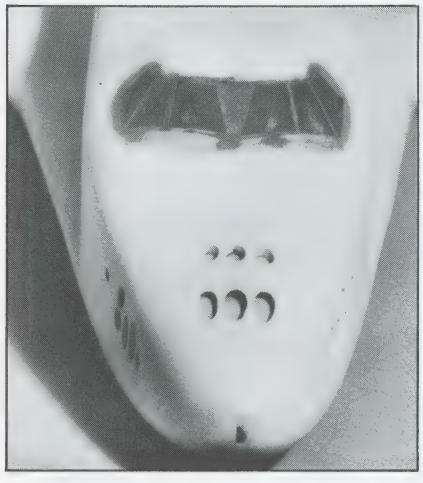
as the fillet. I usually use window glazing compound (available at all hardware stores) for filling areas where sanding would ruin adjacent detail. The compound always remains slightly flexible, and therefore can be used only over rigidly cemented joints or it will crack. Excess material can be wiped off with a cloth or the tip of a knife blade; it can be completely removed with a stiff toothbrush.

Canopies and windshields are always a headache with plastic models. Kit manufacturers usually provide a molded clear styrene canopy or windshield, with all details such as frames and joints cast in place. These lines and joints can be painted, but the masking and careful brush work required is extremely tedious. **Rather than paint the window posts on the Orbiter, I decided to build them up**

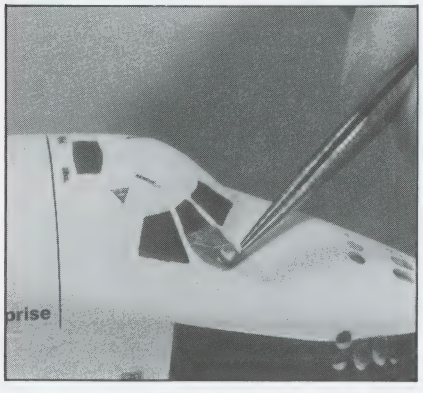


from automotive filler putty. I first masked the clear glazed windshield panels with Sig Stripe-Rite striping tape, a vinyl tape that fits snuggly around corners and sticks well. Scotch plastic tape could also be used. The photo shows putty already applied to one side while the other side is being masked; I suggest you do all the masking first. **After trimming the tape to the exact outline of the window frames, I smeared Green Magic putty all around the windshield area, being certain that it flowed around all sides of the tape.** When the putty had completely dried, I began

sanding away the excess with No. 400 wet-or-dry sandpaper used wet. As I approached the tape, I shifted to No. 600, also used wet. **In this way I removed all of**



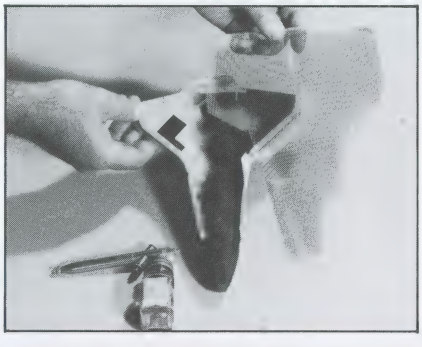
the putty except that which formed the window posts; these now stood out in more realistic relief than on the original molded plastic. The Sig tape remained in place, to protect the clear windshield, until all painting, except the final clear coat, had been completed. **I removed the tape by inserting a pin at the center (not the**

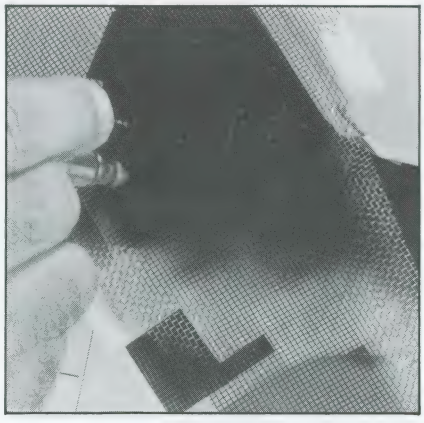


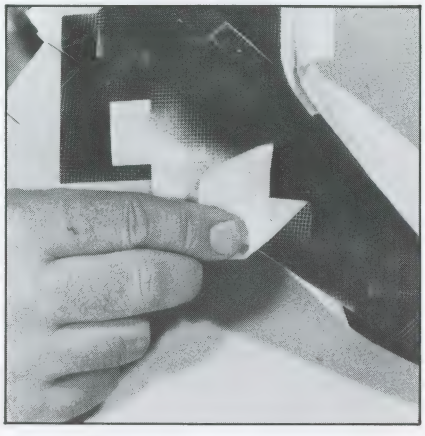
edge) of each piece, lifting gently so as not to break the edges of the putty posts, and then pulling away the lifted tape with a tweezers.

Rockwell International, builder of the Orbiter, told me that the craft is painted in complex patterns of semigloss and nongloss gray-ivory off-whites. In photographs, however, only two shades of white are visible: a pure white around the nose and cockpit and at the rear of the fuselage; and a creamish white over the wings, vertical stabilizer, rocket nacelles, and the fuselage the length of the payload bay. I painted all of the white areas with Floquil reefer white, producing the pure white. I then masked the creamish white areas and sprayed them with Floquil Hi-Gloss, which dried to the proper cream color.

One challenge remained: How to simulate the heat shield ceramic tiles that line critical areas of the wing and fuselage. These black tiles are one of the most distinctive features of the Orbiter, but scribing them individually at 1/144 scale would be a lifetime job for a professional engraver. I would have to be a Swiss watchmaker to consider cutting out and applying thousands of drafting tape tiles. Because a model need not (and can not) be an exact representation of the prototype in miniature, but should represent a convincing illusion of the full-size object in miniature, I decided it would be perfectly acceptable modeling practice to simulate the tiles with a stenciled application of black paint. After masking, I primed the to-be-tiled areas with Floquil SP lettering gray. **I airbrushed Floquil engine black through a stencil made of ordinary wire**







window screen held in the proper diagonal positions, sequentially masking different areas, to match the varied tile patterns on the Orbiter. I held the screen about $^{1}/_{16}$" from the surface of the model, and kept the airbrush 2-3 inches from the screen. The final effect was quite pleasing.

After assembly of the remaining parts and decaling, the entire model was sprayed with a protective coat of Micro Scale Micro Flat, although Testors Dullcote could also have been used. The Orbiter was complete.

Airbrushing the 747's shades of silver

Don Klein

THE bare-metal finish of many prototype aircraft is one of the most difficult finishes to simulate in modeling. When the effect is carefully duplicated, however, the appearance is striking.

We were introduced to the bare-metal finish of the Apollo spacecraft in Chapter 2. If Apollo was a giant leap for mankind, the NASA 747 space shuttle ferry craft is a giant leap for modelers attempting to reproduce metal finishes. The NASA 747 is a panoply of aluminum shades and tints, resulting both from normal surface oxidation of panels and from the replacement of many panels during the aircraft's conversion. The "Boeing gray" paint on portions of the empennage and fuselage reinforcement panels adds further diversity to the color scheme, as do the red, white, and blue windowlines left from the 747's service with American Airlines. No. 905 presents a real challenge to the modeler.

I first had to decide which metallic paints to use. Thin-body metallized plating lacquers produce metal finishes with almost no grain, and they can be buffed to produce slight color variations from panel to panel, thereby simulating the varied panel patterns of prototype aircraft. I decided not to use any of the plating lacquers for several reasons: they are not available at many hobby shops; they must be carefully sealed after application to prevent tarnishing; and, most importantly, any masking must be done with templates. It is difficult to avoid overspray and fuzzy edges with templates. Masking tape can't be used because it pulls up the lacquer.

Because of the large amount of sharp-edged masking that would be required, I chose to use conventional modeling paints, even though these are somewhat grainy.

Before painting, I had to build the model. Generally, it went together without problems, although I did have trouble when the stress from sanding caused several puttied seams to crack open. I sealed these with IPS Weld-On #3 acrylic plastic cement. Before painting, I assembled the entire model except for the landing gear and the horizontal stabilizer.

The Revell 747 is molded in white plastic. I airbrushed a gray primer to give succeeding coats of metallic paint a base on which to "bite." From time to time, I've flouted certain rules of painting, especially those pertaining to what paints can be mixed together or applied over others, in order to achieve special effects. The primer was an example: I mixed an enamel paint (Pactra gray [36622] and a lacquer (Floquil engine black [10]) in a 3:1 ratio.

My first metallic coat was a flat enamel: Pactra aluminum (F-11). Although most of this color would later be painted over, I sprayed the entire aircraft because this seemed easiest and provided a second coat as base for following coats. The Pactra aluminum is rather dark, but I chose it over the aluminums of several other manufacturers because it had the least noticeable grain.

I masked the vertical stabilizer, a center portion of the fuselage, and a panel on the wings from the tips to the roots, and sprayed the entire model with Floquil bright silver (101). I cut the Floquil with mineral spirits. [Editor's note: Diluting Floquil with mineral spirits and applying Floquil over enamel are both serious deviations from manufacturer's instructions and normal sound modeling practice — the results may be unsatisfactory. Floquil recommends Dio-Sol as the only acceptable thinner for their paints. Normally, stronger-solvent paints are applied first, followed by those with weaker solvents. Thus, lacquers are applied first, followed by enamels, followed by water-base latex and acryrlic paints. Application in reverse order is likely to produce crazing or worse.]

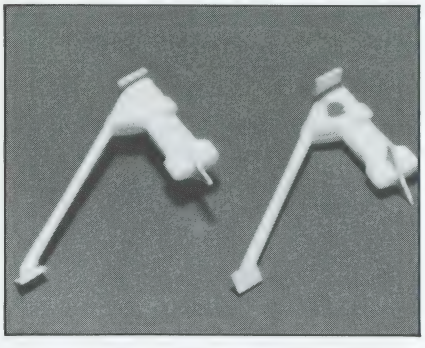
I masked a section of the fuselage just above the wing trailing edge and another just ahead of the vertical stabilizer and painted these sections Pactra silver (II17 in the Authentic International Colors series). This resulted in an especially bright appearance on these sections, although the passage of time and the application of other paints to parts of these sections caused much of the extra brightness to disappear from the finished model. The main purpose — to create still another distinctive hue — was realized, however.

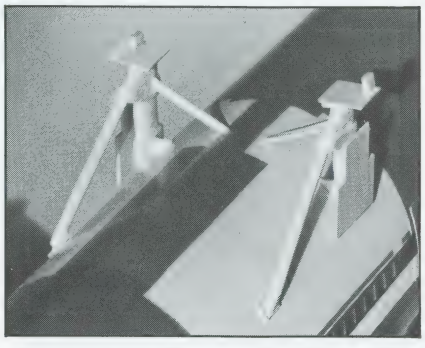
I studied photographs and did other research so I could mix a color that would best match the Boeing gray on portions of the tail and on reinforced sections of the fuselage. Boeing reported that Federal Standard 26492 gloss gray would best match their paint's color, but I decided that Federal Standard 36495 lusterless gray would look more authentic on the model. I matched this color by mixing 9 parts Pactra tinting white (IP-104) with 1 part Pactra light blue (IG-10), and added a drop of Pactra tinting black (IP-105). All paints were from Pactra's Authentic International Colors series. I used photographs as my guide to the exact placement of gray areas. After the paint had dried, I cemented the horizontal stabilizers in place.

Although the kit decal sheet contained the windowline livery, only the red and blue stripes were printed, with a transparent section to represent the white center stripe. I would have to paint a white line the length of the fuselage so that the white would show through the transparent portion of the decal. I masked a strip a little wider than the stripe would be with Scotch Magic tape and filled in behind the edge of the Magic tape with masking tape. To guard against overspray, I added masking tape above and below the strip. I airbrushed with Pactra tinting white and removed the masking after the paint had dried for a few minutes. Even though I waited at least two days between each coat for the paint to dry during the masking and painting process, the masking tape sometimes pulled up small portions of the paints. Metallic colors are particularly susceptible to pull-up. My final step was to touch up areas where the paint had pulled off. I used Floquil bright silver (101) as the base for the touch-up paint, but added drops of black and brown or blue. The Floquil brown added to the silver and black produced a bronze tinge that simulated titanium, and the Floquil blue gave a cast that resembled magnesium.

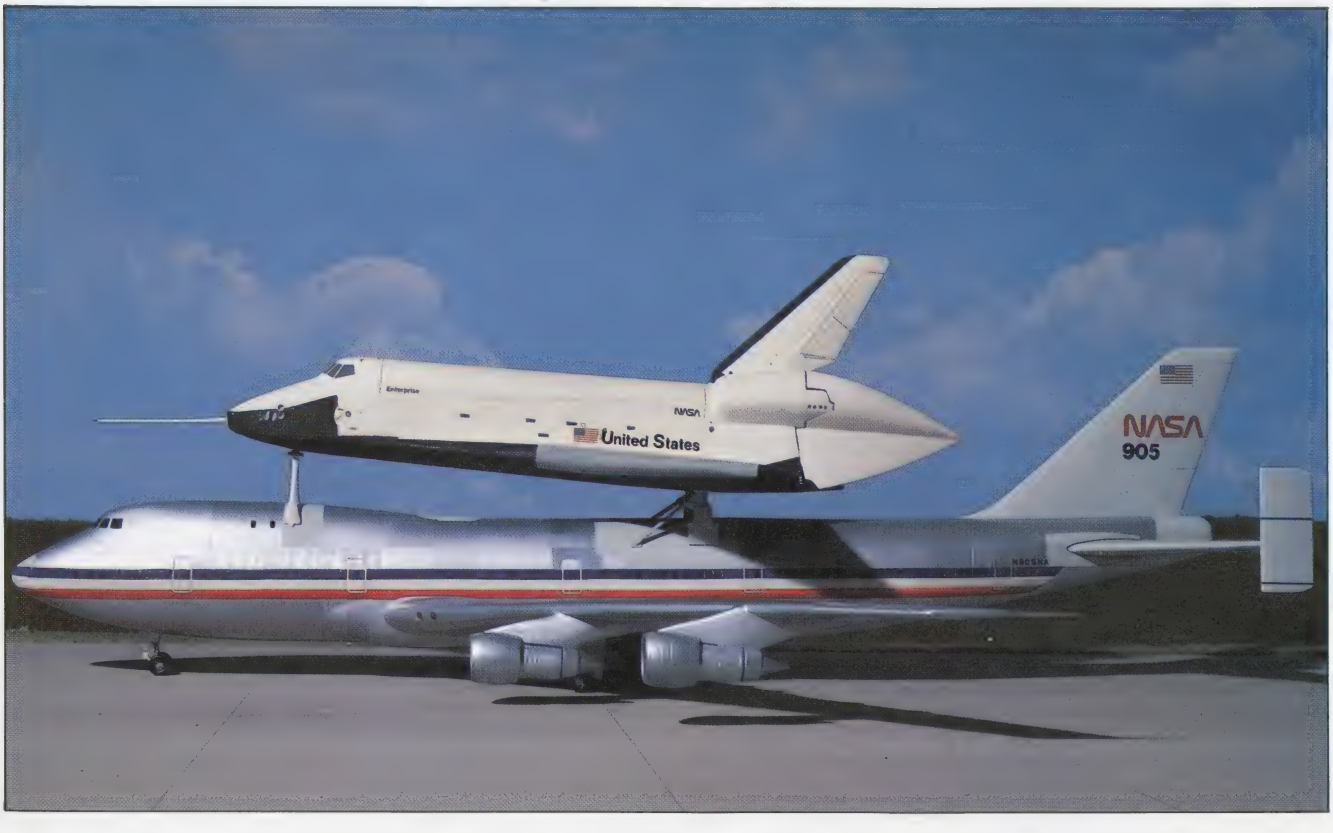
As I prepared to apply the decals, one problem had to be solved: How to reproduce the word "American" that is faintly visible on the sides of the prototype's fuselage. I first planned to apply a decal

of the airline's name — available on the decal sheet supplied with Monogram's model of an American Airlines DC-10, spray over it with silver of a different shade, and then remove the decal. Experiments with a spare fuselage showed this method was difficult. I finally cut the letters from the decal sheet and placed them on a piece of drafting tape. Drafting tape is similar to masking tape, but the adhesive is less strong, so that it removes more easily. Next, I cut over the outline of each letter until I had cut a stencil of the word. I placed the tape on the side of the fuselage. Loose sections of letters, such as the pyramid-shaped center portion of the capital A, were pressed directly to the fuselage. I sprayed the letters with Floquil bright silver (101) with a drop of Floquil engine black (10) added. I removed the tape, placed it on the other side, and repeated the process. I was now ready to apply the decals. I had to trim a little of the red stripe where it passed over the wing because either the model or the decal is slightly out of scale in this area, but generally the decals went on well and looked good. The decals were treated with Walthers' Solvaset decal setting solution and then coated with Micro Scale gloss overcoat, sprayed directly from the bottle.





The support pylons are not the model's best feature. A dedicated modeler would consider building more accurate pylons from scratch. But because my main purpose in building the 747 was to duplicate the multi-hued finish, I used the front pylon as supplied, and only modified the rear pylons. I sawed a slot in the bottom of each rear pylon and inserted a triangular piece of sheet styrene, contoured along the hypotenuse to fit the fuselage contour. These pieces made better contact with the fuselage and allowed for positioning up or down. I also cut small squares from the styrene to use as pads at the forward end of the support braces. I removed the locating pegs at the top of the pylon, filed the tops flat, and cemented squares of sheet styrene platforms in place. I later attached new locating pegs to these platforms. Putty was applied where necessary and sanded. The pylons were painted a flat gray and cemented in place with Hot Stuff ACC. Using photos of the prototype as my guide, I cut inverted-T panels from sheet styrene, painted them flat gray, and cemented them to the outside of the aft support pylons. Next, I cut a length of stretched sprue and cemented it from the right pylon to the top of the fuselage. Smaller-diameter sprue was used to make a V-shaped brace from the left pylon to the top of the fuselage. This was cemented with Hot Stuff. I fashioned new attaching pegs and temporarily positioned them on top of the platform supports with rubber cement. Using the Orbiter vehicle, I was able to adjust the attaching pegs until they were perfectly positioned with the holes/slots in the underside of the Orbiter. After scraping away the rubber cement, I permanently affixed the pegs with Hot Stuff. I brush-painted the pegs and braces flat gray.



© 1968 MGM; courtesy Robert Cain/T.V. Chariot Productions

Visionary Space Shuttle from 2001...

ORION III

JAMES E. OBERG

THE ORION III space shuttle represents a hypothetical rocket plane of the end of this century. Arthur C. Clarke, the noted author and futurist, described the vehicle in his movie script and his book *2001: A Space Odyssey,* produced before men had even been to the moon.

Clarke's vision was, as usual, remarkably accurate. The vehicle he described could one day be a logical successor to the first Space Shuttle Orbiter built by NASA.

The whole justification of a space shuttle vehicle is to reduce the complexity and cost of getting people and cargo into orbit. To do this, the system should be both reusable and simple to operate.

The cost of *energy* in kilowatt hours to put a man into space can be paid in a handful of dollars. The price of the ticket on Apollo spaceships, or even on the NASA Space Shuttle, was in the tens of millions of dollars. Why the difference?

Clark's *Orion* underscores that very question. He speculates that a single flight (in 2001 AD) would cost perhaps a million dollars — many times cheaper than present costs (although the inflation rate may play havoc with Clark's prognostication). Costs are kept down by using high energy fuels, by reusing every component of the vehicle, and by relying on automation to reduce the tremendous "people cost" of the familiar scenes at NASA's Mission Control, showing dozens of technicians bending over consoles.

Today's Space Shuttle is only the first of a family of space vehicles which will open and secure a permanent bridgehead into orbit. After a decade or two of faithful service, NASA's first design will be retired with honor. New designs, such as that forecast by Clarke, will make the *Enterprise* and her sister ships obsolete.

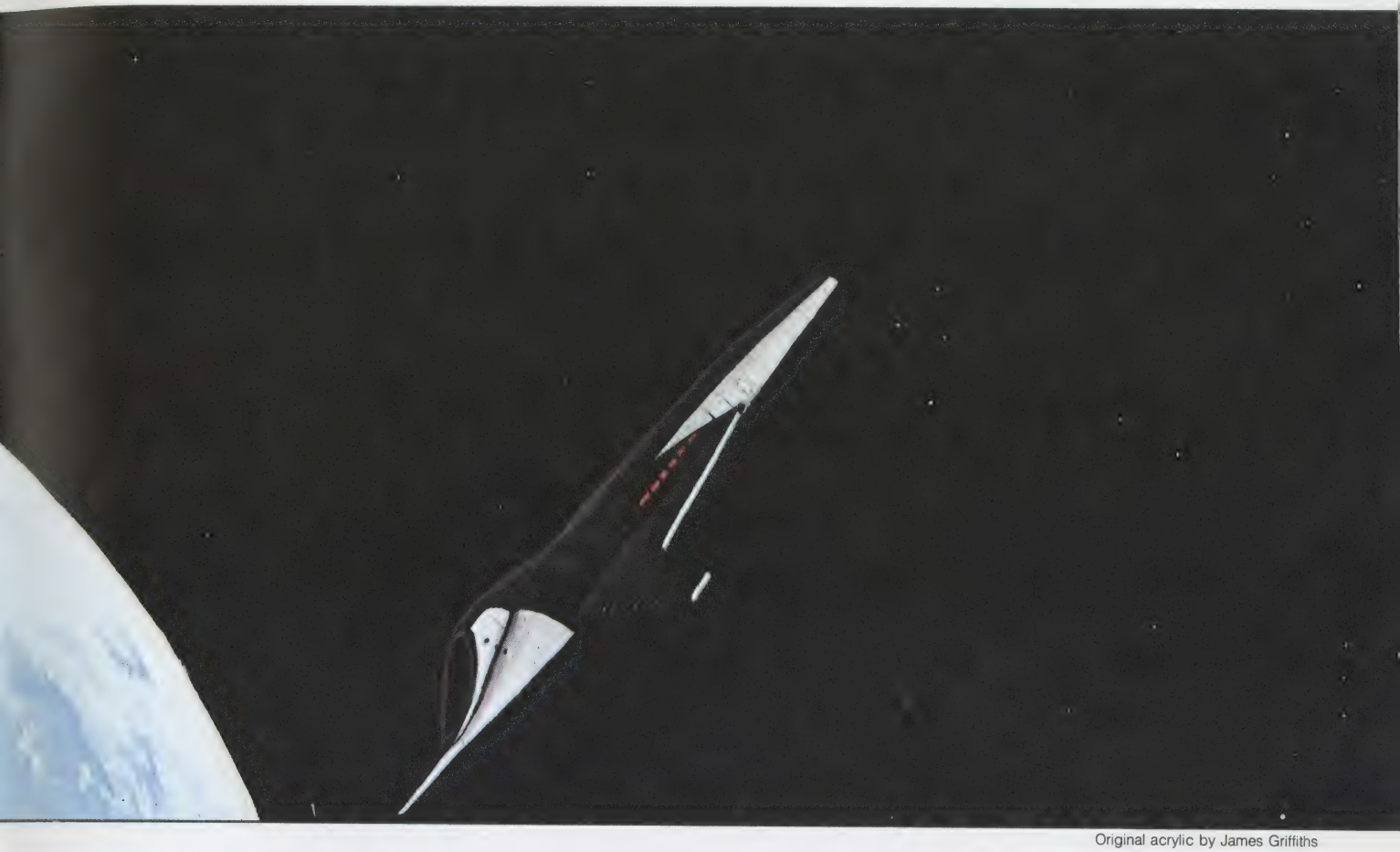
Orion is a winged vehicle that is the second of two stages. The first stage (not depicted in the movie) has a 200-foot wingspan and is probably similar in shape to the smaller *Orion*. The *Orion* is boosted piggyback style halfway into orbit by the first stage, which then returns to the launch site to be serviced and refueled. The total liftoff weight of both stages is less than half that of the NASA Space Shuttle because its engines and fuels are much more efficient.

In the book and movie, *Orion* is piloted by a pilot and copilot. A single stewardess serves in the passenger cabin (although only one passenger is making the special flight).

Clarke makes reference in the book to a passenger cabin of 20 seats. The Aurora model, which appears to be an accurate copy of the movie model, has five major window placements on each side of the fuselage which, assuming two-plus-two seating, would substantiate a cabin capacity of 20 people. However, the mock-up of the interior used in the movie clearly has nine rows of seats in two-plus-two configuration, equaling a seating capacity of 36. A capacity of at least 36 would be the most logical if the *Orion* were to be truly viable economically. No mention is ever made, of course, of the cargo capacity of the *Orion*; but any appreciable capability in this area would contribute to the practicability of the vehicle and, perhaps, be more important than the passenger capacity.

In providing convenient and inexpensive transportation between the earth and an orbiting space station, the *Orion*-class spaceship fleet could prove its commercial feasibility through operation by a private company (by Pan American in the movie, a not implausible choice).

For takeoff, the *Orions* and their mother ships are



Original acrylic by James Griffiths

hurled down a long launching ramp by a space-age equivalent of an aircraft carrier launch catapult. With the *Orion* on its back, the engines of the mother ship accelerate at a rate of twice the force of gravity for a little less than 10 minutes. At this point the mother ship breaks away, leaving the *Orion* to use its own engines to propel itself into orbit. The thrust is a gentle one G, just as strong as earth gravity; and it takes an additional 15 minutes to reach orbital velocity.

Once the engines cut off, the ship falls forward at a speed great enough so that, as earth's gravity inexorably curves it toward the ground, the curvature of the earth causes the ground to curve out away from below the spacecraft. It is an artificial satellite in free fall. The passengers are weightless inside. However, contrary to popular misconceptions that will probably still be strong in 2001 AD, the spaceship is not (nor are any other satellites) in "zero gravity." In fact, it is the very strong gravity of the earth which holds the spaceship in its low orbit.

Clarke did not specifically describe a propulsion system except to refer to rocket engines. Aurora elaborated on the propulsion system for inclusion in the plastic model — and selected a nuclear power plant, a reasonable if unimaginative choice.

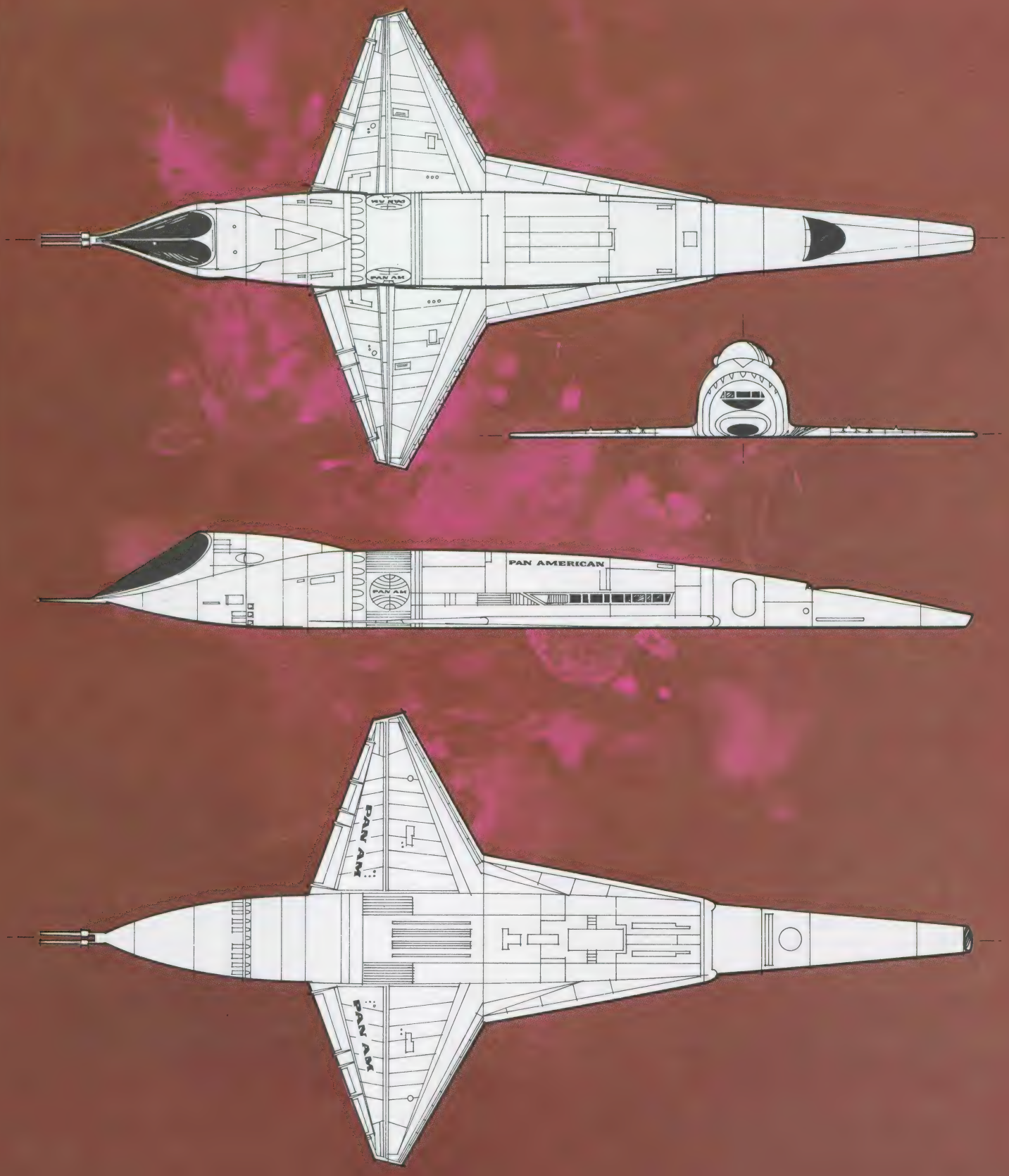
To date, space rockets have obtained their thrust by burning propellants (a fuel is burned in the presence of an oxidizer) at high temperatures and pressures, producing a spurt of gases which pushes the rocket forward. With nuclear power, any type of inert liquid, such as water, could be passed through heat exchangers near the nuclear reactor where it would burst into steam, producing the same sort of hot gas stream for thrust. The gas would not be radioactive since it would not mix with the reactor elements, but only pick up heat.

Chemists are studying new types of rocket fuels to be used in the decades ahead. A fuel is needed that has a high energy level and also a high density. The highest energy fuels used in Saturn and Space Shuttle rockets are liquid hydrogen and liquid oxygen. Unfortunately, liquid hydrogen is lightweight (it is not dense), so very large and heavy tanks are needed to carry a sufficient quantity. If the fuel could be made denser, smaller and, hence, lighter, fuel tanks would be sufficient.

Rocket propulsion experts speak of bizarre forms for hydrogen such as metallic hydrogen (which in nature exists only in the core of the planet Jupiter) and atomic hydrogen. Also mentioned are fluorine and other fuels which are extremely difficult to produce and handle and which put out dangerous combustion products (most of the "smoke" from a Space Shuttle launching is pure water vapor — steam!).

Once in space, the need for high-thrust rockets diminishes. Instead, highly efficient but weak rockets are needed that can fire for months at a time — pushing spacecraft to speeds unimaginable today. Ion drives will use the metal mercury as "reaction mass." Antimatter drives are still considered "far out" but not impossible. Giant thin sails might catch the solar wind and tack their way across the solar system. Enormous contraptions known as electromagnetic slingshots will derive thrust from the expulsion of any waste mass at all, including the previous day's garbage.

Space flight will still require earth facilities. Someday, for the sake of efficiency, space stations may circle the earth just around the equator. Launch sites must also be along the equator (Clarke's *Orion* still uses Kennedy Space Center), perhaps turning cities like Singapore and Quito, Ecuador, into space-age giants.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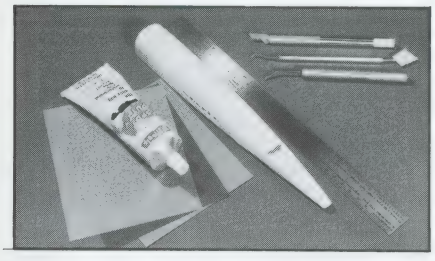
Tools and techniques for panel scribing

KIT: Space Shuttle Orion from *2001: A Space Odyssey*
MANUFACTURER: Aurora, U.S.A., Kit No. 252
SCALE: 1/144
DIMENSIONS: Length — 14 3/4"; wingspan — 7"; height — 1 7/16".

Bob Hayden



Putty, Flex-I-Grit, steel straightedge, hobby knife, and special scribing tools were used on the Orion. To scribe wide troughs, use a razor saw (not shown).

THE SLEEK space clipper *Orion* from Aurora is a small-scale, competently executed kit with relatively few parts.

The *Orion* model includes many grooves that run around the fuselage, and when the fuselage halves were cemented together and the seams filled with putty and sanded, many of these grooves were filled or reduced in depth.

We can't abandon these filling and smoothing operations because they are essential in turning a stock plastic kit into a realistic scale model, so we have to come up with some method to restore the recessed grooves.

Basic scribing techniques —— Scribing plastic is fundamentally a process of scraping away material from a narrow groove in the surface of the model. I say scraping rather than cutting, because the action involved in removing material is much more like that of a paint scraper than a knife. The plastic scribing tool is shaped like a cutting tool on a metal lathe, and it removes material by peeling it back from the surface of the stock.

Re-scribe fuselage grooves, or any grooves for that matter, only after all filling and sanding operations have been completed, but before priming. If you have only one or two short grooves to restore, you can frequently get away with using a hobby knife blade as the scribing tool. Lay out the location of the groove with a sharp pencil and scratch over the line with the back edge of the knife — I find the Nos. 11 and 16 X-acto blades are the handiest shapes for this work. Always use a steel ruler or other metal straightedge to guide the tool. **When you have a shallow scratch mark, turn the knife blade 90 degrees —**

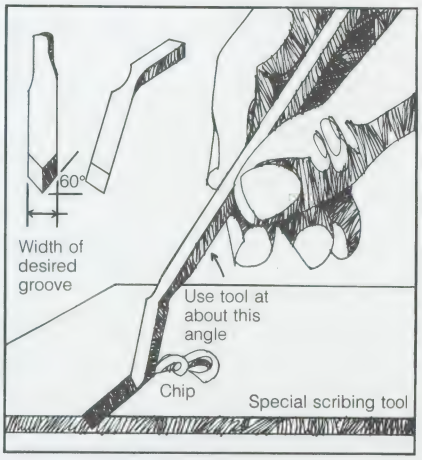
so the knife edge is *across* the intended groove — and gently move the blade sideways to remove material.

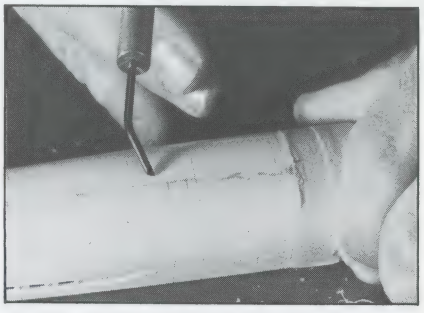
The hardness of the plastic will have a lot to do with how well your scribing job goes, and you'll find hardness varies quite a bit, even in different kits from the same manufacturer.

Several light scribing strokes are always superior to a single heavy one, because light strokes allow better control of the material removal and give you the ability to vary the pressure on the tool to obtain an overall uniform depth in the groove. Also, you won't mar the model as badly if your tool should leave the intended path. Most filler putties, including the green varieties, will take scribed grooves cleanly if the putty is *completely* hardened and the puttied area is scribed very slowly, removing only a little bit of material at a time.

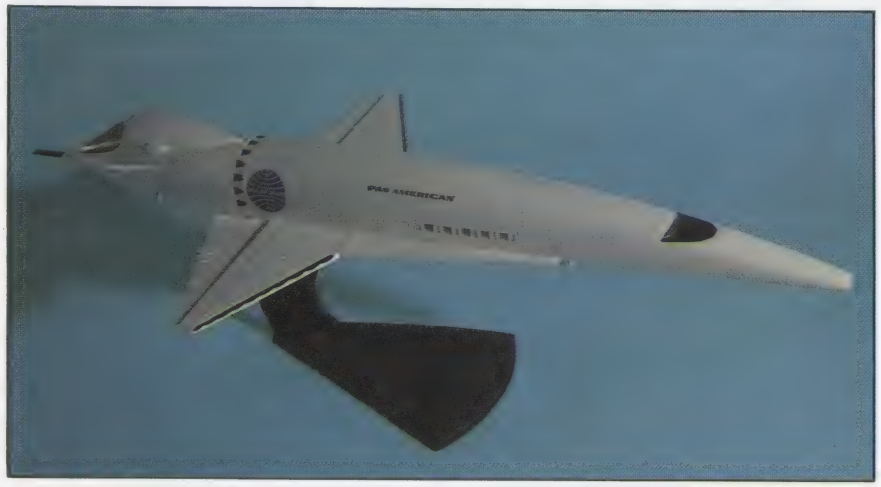
A special scribing tool — If you find you are doing a lot of re-scribing, adding many additional panels to kitbuilt models, or building from scratch, it's definitely worth the time required to make a special scribing tool. The details of the tool are shown in the drawing. You can make it from a broken or surplus dental tool — handy because it already has a comfortable shape — or a piece of drill rod, or even a worn-out file. You can do the grinding on a regular grinding wheel, or even with a small wheel chucked in a Dremel tool if that's all you have. In use, the tool should be honed occasionally on an oilstone to keep it sharp.

After all scribing work is done on your model, rub 600-grit sandpaper — wet — along the edges of the grooves to polish away any burrs and round the edges slightly. Don't overdo this, just relieve the edges a little to get rid of the too-sharp look.





Fuselage detail was protected with masking tape when scribing with special drill-rod tool.



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The evolution of Star Trek's starship...

ENTERPRISE

RICHARD G. VAN TREUREN/ CHRIS TIETZ

WHAT'S the single most famous spaceship in the annals of science fiction? Few interplanetary vehicles have captured the public imagination to the degree the starship U.S.S. *Enterprise* has. It achieved widespread recognition through the airing of 79 *Star Trek* television episodes during 1966-1968, but gained an even greater following as the series became a TV syndication hit during the ensuing decade.

The *Enterprise* hardly maintained a steady technological course through the universe of the United Federation, however. Television shooting schedules, budget considerations, and script development combined to create a starship whose configuration and capabilities slowly evolved through three television seasons. The *Star Trek* mystique that blossomed as the series prospered in syndication also saw a mythological-like development of the *Enterprise* as an outpouring of drawings, plans, and technical papers hit the market.

In a sense there are at least two *Enterprises* — the fictional vehicle that introduced Captain Kirk, Mr. Spock, Dr. McCoy, Lt. Uhura, and others of the crew to countless dangers and adventures as they boldly went where no man had gone before; and the balsa, hardwood, plastic, and metal creations that worked in front of the cameras,

one of which is on permanent display in the Smithsonian Institution. Throw in the technical drawings and plans, plus the revised *Enterprise* of the movie, and the lore of the ship proceeds at warp-drive speed.

Let's first review the fictional *Enterprise* that has been integral to so many *Star Trek* plots.

ENTERPRISE INCIDENTS

In the early 2100's, the United Federation of Planets set down plans for a fleet of a dozen starship deep-space cruisers. Their mission would be to patrol the galaxy and maintain interplanetary peace and security, and on occasion, seek out and make contact with new civilizations.

One starship, the United Space Ship *Enterprise,* was named after several ancient water-borne vessels — including the first atomic-powered aircraft carrier in the United States Navy. Components were built at the San Francisco Yards, approximately at the historic site of a U. S. Navy repair depot used a couple hundred years earlier, and lifted into earth orbit where they were assembled.

The completed *Enterprise* measured some 289 meters long by 127 meters wide and grossed 172,365 metric tons. Although it was roughly the same physical size as the warship that bore the name two centuries before, the starship outweighed the old naval vessel twice over.

The completed *Enterprise,* then, consists of a saucer-shaped primary hull connected by a large dorsal strut to a fat, cigar-shaped secondary hull. Long struts extending upward diagonally from the secondary hull support the two long, cylindrical nacelles housing the warp-drive propulsion units.

For a mission that takes the crew away from home for years at a time, the *Enterprise* provides spacious living quarters. The ship has numerous recreation rooms. There are excellent food preparation facilities. The hospital, while still called "sickbay," has life-function beds and is more than adequate for tending to the crew. Intraship transportation is via turbo-lift — enclosed capsules that speed vertically and horizontally through miles of airless interconnecting passageways.

The ship is designed for a crew complement of 430 (the smaller ship shown in the pilot film was projected for "203 lives," while early production envisioned a "thousands of feet" ship).

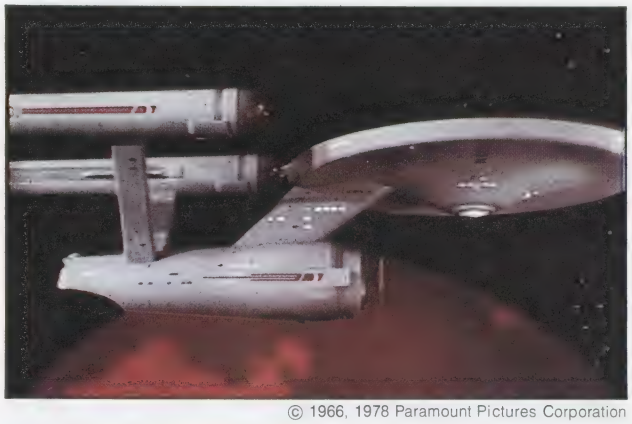
The bridge, perched atop the saucer-shaped primary hull, is the overall command center. All the ship's functions are monitored and controlled from here: communications, computers, engineering, environmental, helm, navigation, sensors, and so forth. Weaponry and such engineering functions as engine operation and power generation are remotely controlled from here. (Early episodes showed a phaser control room and a large engineering room where commands from the bridge were carried out, much like today's naval vessels. Later shows, under tighter budgets, reduced such complex operations to the pressing of some buttons on a bridge panel by a single crewmember.)

During battle or other situations when the exposed bridge might be vulnerable, duplicate controls are manned in the well-protected auxiliary control room. More than once it has served as a disadvantage when undesirables such as the rebels in "The Way to Eden" have taken control of the ship from it.

Most of the dangers facing the *Enterprise,* in fact, have not come in the form of enemy spaceships offering classic battle, but in the form of invading aliens, creatures, and entities.

One way to remove such internal threats is via the transporter, which changes matter into energy, sends it to a predetermined line-of-sight destination, and restores it to its original form. The transporter, however, was not created as a means of dealing with the sophisticated threats of later story lines. Because the *Enterprise* cannot land on planets, the transporter was introduced as a means of projecting crewmembers from the starship to planets and other spaceships, or simply, from adventure to adventure. The necessity for the device was more practical than dramatic: The pilot film ran over budget, so there was no money to build the "shuttle rocket" described in the series format. Shuttlecraft (the normal complement has variously been given as two, four, and six) did appear later, but by that time the transporter was well established. It remains as one of the more controversial scientific and ethical aspects of the ship, and can pose considerable dramatic difficulties (among other things, making escape from almost any situation seemingly possible at any time).

Although the transporter actually inspired some plots (in "The Enemy Within," a malfunction caused Captain



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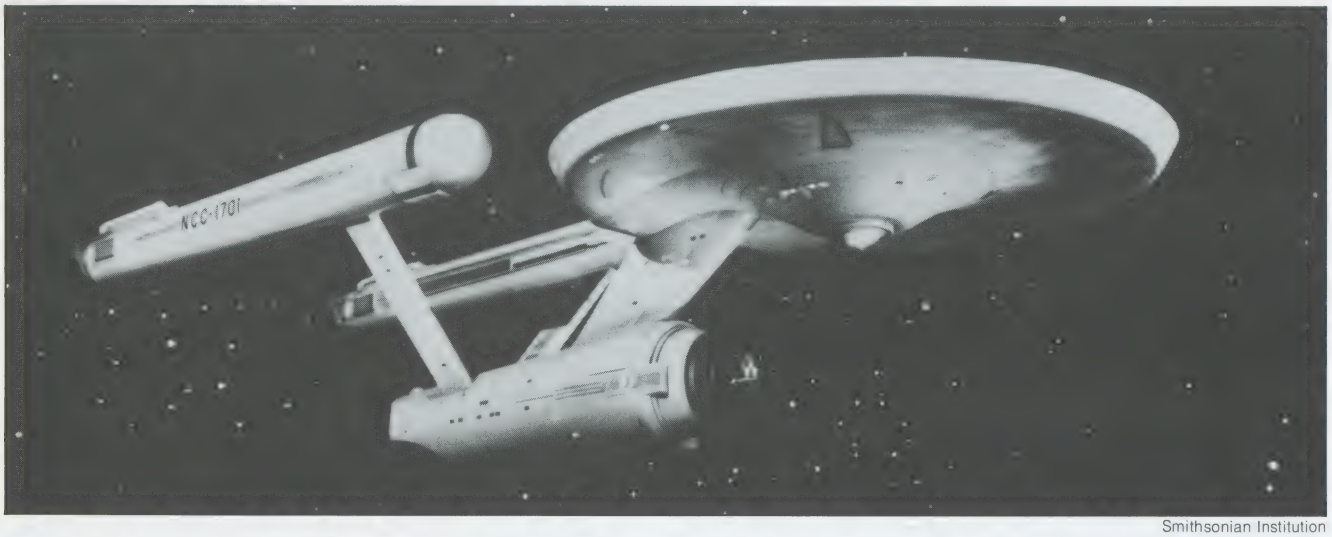
Kirk to be split into two identical persons — one representing his evil aggressive personality and one his gentle half), its most frequent application, besides transportation, has been as a sort of reverse *deus ex machina*: In "Wolf in the Fold," a force known among other names as Jack the Ripper and possessing a man's body at the time was placed in the transporter while drugged and beamed off the *Enterprise* into deep space; in "The Changeling," the little machine Nomad, which had threatened to blow itself up along with the *Enterprise,* was beamed off to harmlessly explode in space; and in "The Trouble with Tribbles," furry animals bent on uncontrolled reproduction were projected into the engine room of a nearby Klingon ship.

For classical ship vs. ship combat, the *Enterprise* is armed with phasers and photon torpedoes. The phasers, which are a beam weapon, are fired from positions on the top and bottom of the primary hull. The photon torpedoes, which contain matter and antimatter suspended apart awaiting combination at detonation, can be fired directly at a target or laid out as in a minefield.

On two occasions the *Enterprise* tangled with Romulans — Roman-style warriors in small ships painted like birds of prey. The more serious encounters involved the



Smithsonian Institution

Famous publicity photo of the Enterprise features the film production version with a star effect background added.

Klingons — totalitarian hordes who openly oppose the Federation. A great battle between Klingon and Federation fleets was only narrowly averted by the intervention of a superior civilization. One unshielded and abandoned Klingon ship met destruction at the business end of the *Enterprise's* phasers; another one once escaped with minor damage.

Defensively, the *Enterprise* is equipped with protective deflectors that act as a shield that envelops the ship. Sensors (the main sensor dish or screen is located at the bow of the secondary fuselage) are used to gather data on planetary bodies and special phenomena. The ship is also equipped with a tractor beam that can attract, hold on to, or repell objects in space. The S.S. *Botany Bay*, a sleeper ship carrying occupants in suspended animation from 20th century Earth, was held alongside the *Enterprise* in this way ("Space Seed").

Descriptions of the power and propulsion systems of the starship have been well developed in some areas and left vague in others. Certain contradictions have also occurred.

Critical to power generation are lithium (later dilithium) crystals, although a precise explanation of how they work is never given. They have often been the cause of a major dispute between the Klingons and the Federation. Apparently the crystals perform the function that fuel cells perform in today's space vehicles. The rechargeable crystals provide the energy for such life-support functions as artificial gravity, atmosphere, heating, and lighting, as well as for such systems as the deflector shielding, tractor beams, sensors, and other scientific equipment. The crystals are also intimately involved in the operation of the warp-drive propulsion units, perhaps in the way an automobile battery provides a spark for the motor.

To patrol the vast distances of the galaxy, the *Enterprise* must exceed the speed of light. The power to do this comes from the twin warp drives, in which fuel is annihilated in the matter-antimatter engines.

The speed of the *Enterprise* is measured in warp factors. Warp factor one is the speed of light, and from there the speeds increase geometrically. Maximum safe cruising speed for the *Enterprise* is warp six, while warp eight can be used in emergency situations but places extreme stress on the ship's structure. On a couple of occasions, with the help of intruders (and perhaps with the assistance of less knowledgeable scriptwriters), the speed soared above warp eight without apparent damage. Nomad ("The Changeling") increased the speed to over warp 11; and Losira, a beautiful alien woman ("That Which Survives"), fused the emergency bypass valve for the matter-antimatter integrator, causing the engines to race above warp 14.

For travel at more subdued speeds through solar systems, the starship relies on its thruster (formerly "rocket") engines located at the rear of the primary hull.

Other starships in the Federation fleet have had their share of adventures — not always with the happiest of results. The *Constellation* was lost in the process of destroying a mammoth planet killer that invaded the galaxy ("The Doomsday Machine"). The *Intrepid*, with a crew of Vulcans, was destroyed by a huge space amoeba ("The Immunity Syndrome"). The crew of the *Exeter* was lost owing to a virus contracted from a planet ("The Omega Glory"). The crew of the *Defiant* perished when the ship was caught in an interphase between alternate universes ("The Tholian Web"). Half the crew of the *Farragut* was lost when attacked by a deadly gaseous cloud during Kirk's first starship assignment (the cloud returned to attack the *Enterprise* in "Obsession").

The greatest damage inflicted on starships at a single time came from — irony of ironies — the phasers of the *Enterprise* herself. In "The Ultimate Computer," the *Enterprise*, *Excalibur*, *Hood*, *Lexington*, and *Potemkin* all were gathered (an interesting exercise in its own right considering the vast areas of space the ships normally must patrol) for war game maneuvers. A new super computer was tested aboard the *Enterprise*, and the machine went berserk and believed the war was real. Before Kirk could regain control of his ship, the *Excalibur* was reduced to a battered hulk with total loss of crew and the *Lexington* was badly damaged with many casualties.

Remaining starships specifically mentioned by name in the episodes are the *Constitution*, *Republic*, and *Yorktown.* This makes a total of 13 ships, although Kirk once referred to a starship fleet of 12 ships. It is reasonable to assume that new ships were built to replace those lost, and perhaps even named after the lost ships.

Assignment: Soundstage

RICHARD G. VAN TREUREN

FROM the beginning, the platform Producer Gene Roddenberry wanted to circulate his *Star Trek* characters on presented a problem. Although scientists might have been employed to develop logical spaceship designs, the show's exact future date — and therefore its postulated technology — had not been established. In addition, scientific accuracy rarely yields saleable art. The design had to be esthetically agreeable to the mass audience; it also had to be practical for stage illumination and photography.

Fortunately, the production unit was blessed with several talented men who had aviation backgrounds. Walter "Matt" Jefferies, an antique airplane buff, was instrumental in gathering reference material and developing the spaceship design. After final approval from the producer, Jefferies had whipped up a prototype model by late summer of 1964.

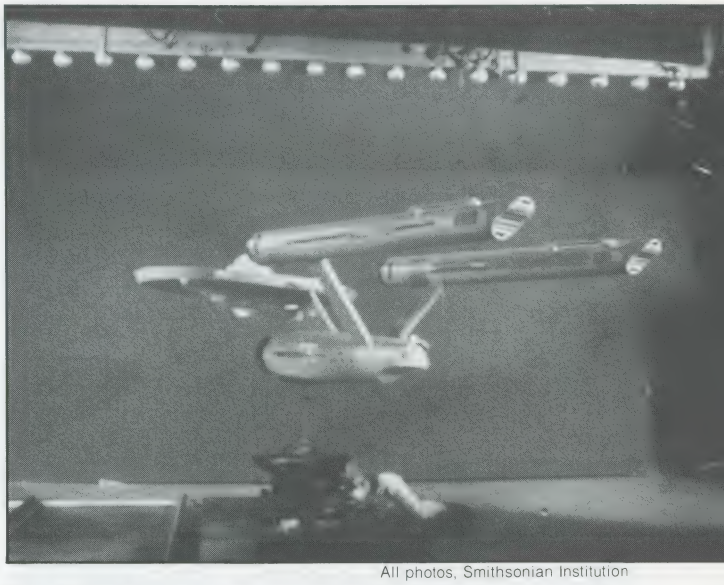
The Howard Anderson Company, an optical effects house near the Desilu Studios, was contracted. Working with Jefferies, the Anderson people constructed a tiny 4-inch wood-and-cardboard miniature. After approval, what might be called the "publicity *Enterprise*" — a detailed 3-foot balsa-and-plastic model — was completed.

It was obvious that a larger miniature wired with lights would be required; the enormous cost would be quite a gamble at this stage, before a script had even been approved. Nonetheless, Anderson got the go ahead to begin. Working with hardwood, balsa, plastic, and metal, the largest miniature ever made for a pilot film was constructed. Power for its numerous lights and flashers was wired through the pipe support of the model's base. The finished model measured 134 inches long; the saucer hull was 60 inches in diameter.

The *Enterprise* miniatures came almost four years before the science fiction spaceship world would be forever changed by the complicated "hardware" ships of *2001: A Space Odyssey.* Still, the *Enterprise* design remains a striking combination of logical prediction and hot-rod art direction. An example is seen in the "NCC" prefix to the hull number. Prior to 1950, standard American aircraft carried an "NC" license number prefix. Racing planes used "NR" and experimental craft were designated "NX." The prefix system could have been used to identify subsequent types of spaceships, since the *Enterprise* was at first a "cruiser class" vessel, neither the smallest nor the largest in what could have been a diverse fleet of star craft.

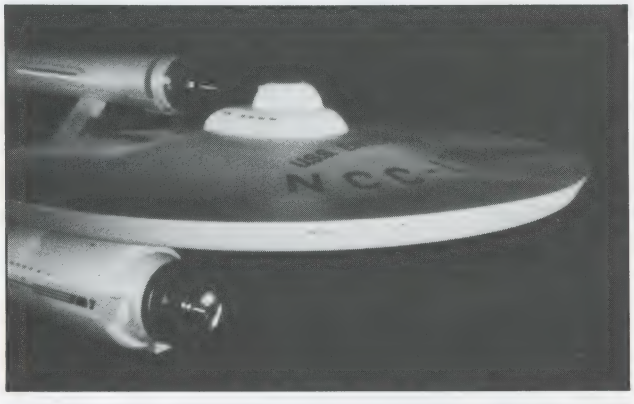
Test shooting got underway in September 1964. Although white coloring was tried, both models were eventually covered in a silver-gray coat. (Variable film stock, optical quality, lighting, and color television transmission would make the ship appear white, green, and blue over the coming years.)

Pilot shooting was completed just before Christmas. Although the final edition of the 63-minute film remains a science fiction classic and television milestone, its professional appearance was hampered by the use of the

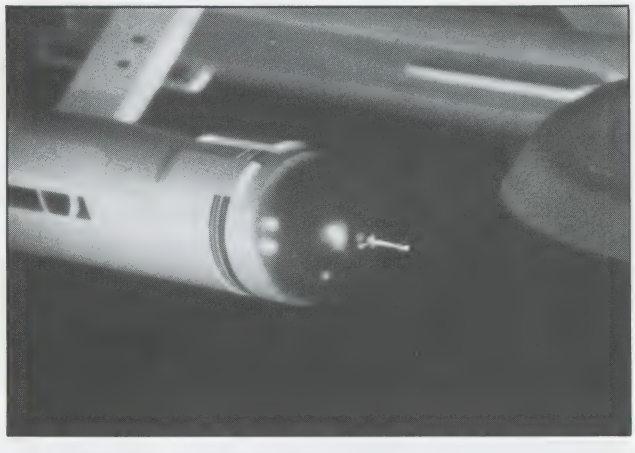


All photos, Smithsonian Institution

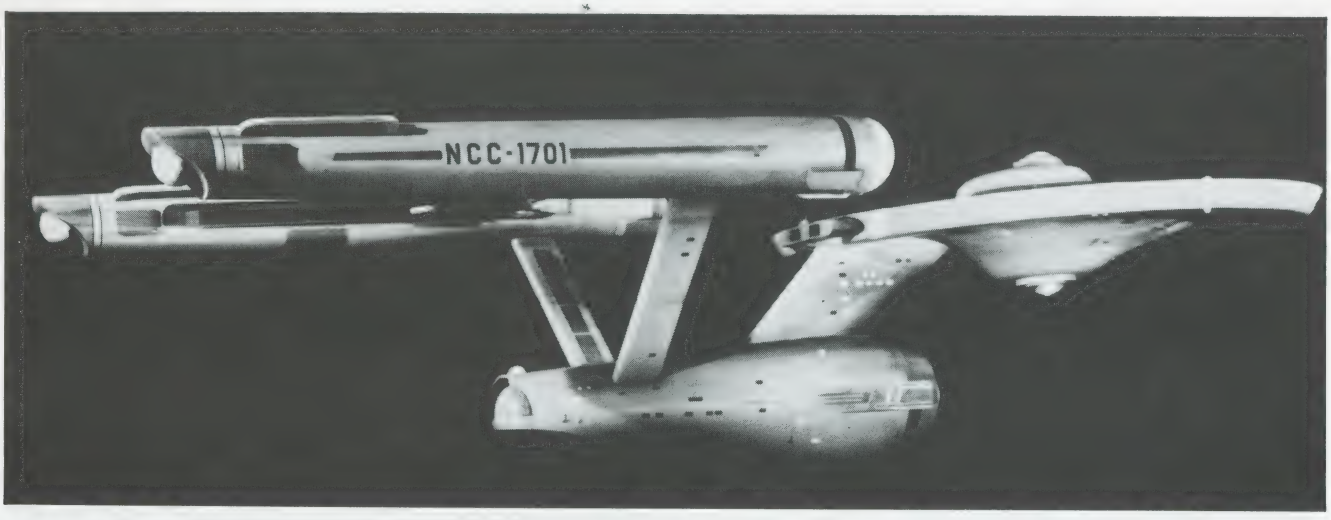
The 11-foot miniature shown shortly after its completion in the fall of 1964. Note the nacelle end caps and port side details, which were later modified.



Front view of the pilot film version shows even finish, enlarged sensor screen, raised bridge cap, and lack of detailing on saucer.



Pilot model nacelle details: Compared to the film production version, note smaller end cap with spike and lack of cross-hatching on the inside of the nacelle and support struts.



After the March 1966 improvements were made, only the model's starboard side was filmed. Note globe-shaped end caps added to the nacelles, the cross-hatched panels added to the nacelle slots and pylons, and detail given to hangar bay.

two smaller miniatures. As is well known, a poorly conducted audience test led to its rejection and NBC's eventual agreement to a second pilot.

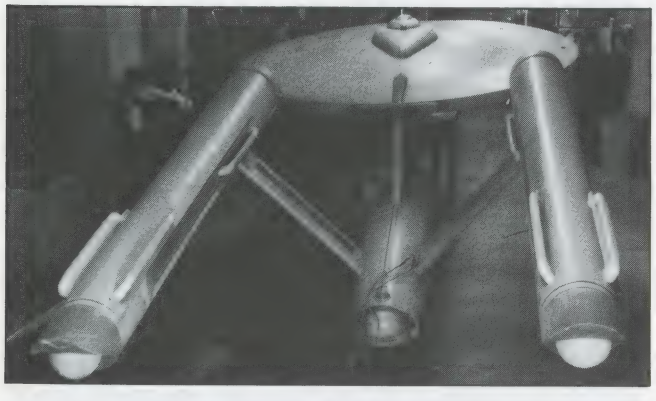
Although the theoretical size of the ship was enlarged for the second pilot, no major changes were made in the miniatures in 1965. The small cardboard and balsa model was no longer used and has since been lost. There was no money for an actual shuttle vehicle, so no hangar bay was necessary. In fact, publicity drawings made later that year showed flame and smoke blasting out of the lower aft end.

The new pilot, stalled from network viewing until the proper time in 1966, sold the series. Almost immediately the yard-long "publicity *Enterprise*" was employed in taking publicity pictures. By March of that year, the decision was made to improve the miniatures; models made for a chance pilot film could not hope to stand up to weekly viewer scrutiny. The following month saw the Anderson Company begin modifications to the 11-foot model.

The top saucer bridge section was lowered. Cross-hatched panels were added to the nacelle struts and inboard nacelle slots. The "main sensor screen" was shrunk in diameter. Lighted pods were added to the nacelle "exhaust" cones. And, at last, the hangar bay doors at the aft of the secondary fuselage were defined.

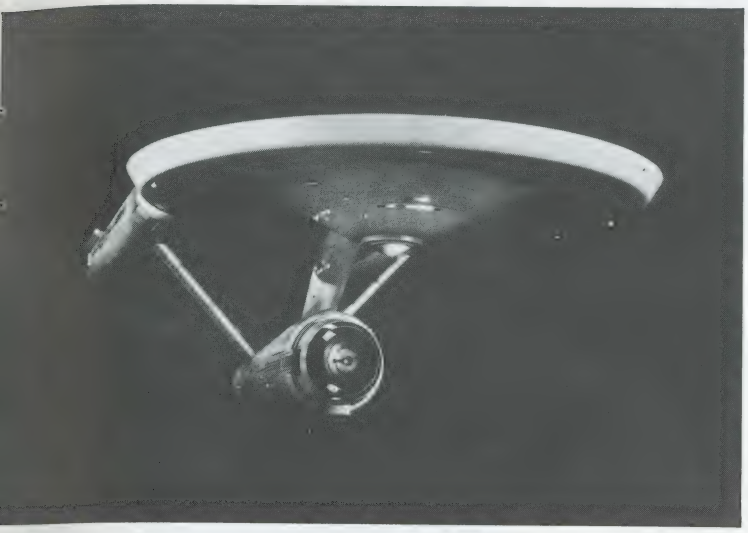
The most difficult part of the project was the addition of the nacelle cap lighting effect. After removing and discarding the original spiked caps, the wood was hollowed out to house large motors. Small Christmas tree lights were added to newly fabricated disks, which were mounted on bearings and connected to motors for rotation. Slip rings were fashioned to provide power to the little winking lights; once the new translucent caps were added, no single light could be followed through the complete circle of rotation.

The heavy wiring required to operate the new effects could not be fished through the existing support pipe, so the entire port side of the miniature was torn up to route the cables. When the model was refinished with a beautiful "weathered" appearance, the port side was left unpainted; it would never be seen on camera again.

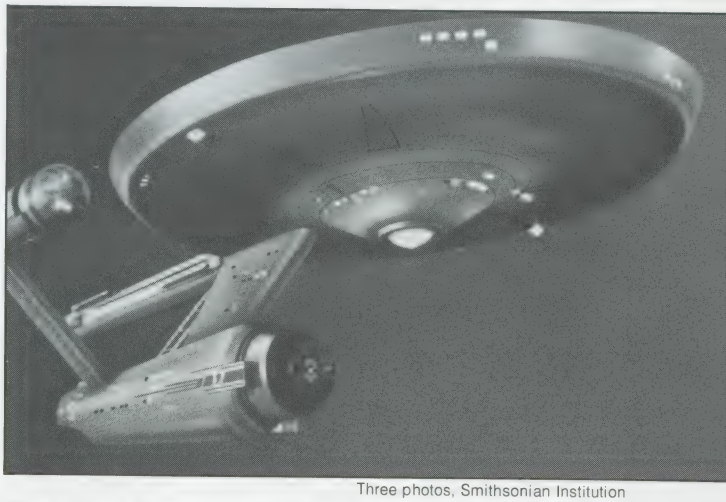


Both photos, Smithsonian Institution

The Enterprise 11-foot miniature as it appeared at the Smithsonian Institution's Silver Hill, Md. restoration facility after being uncrated and reassembled for inspection. Exposed wiring on port side reveals why that side never appeared on the TV screen. Besides painting and other cosmetic work, the Smithsonian restoration team had to replace some missing plexiglass windows, fabricate new front end caps for the nacelles, and install a new main sensor dish.



The 11-foot model was carefully weathered in 1966. Front view shows more detailing and smaller sensor screen.



Three photos, Smithsonian Institution

The underside saucer numbers were turned around late in the first season to be more readable from the most used camera angle. The larger, spikeless cap replaced the nacelle cap used on the pilot film model.

The smaller model, reclaimed from picture taking, was reworked to copy as many of the static changes as possible. The model wound up with a portion of its mounting bracket permanently affixed to the lower hull.

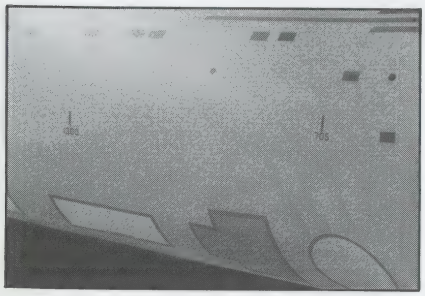
Publicity photos were taken of the 11-foot model on a darkened stage, allowing stars to be printed in later without a costly optical effect. For some questionable reason, publicity photos also were taken of the yard-long model suspended in front of a *sky*-textured background. These unflattering pictures, complete with visible wires and the dangling mounting bracket, have somehow become the most widely published photographs of the spaceship.

Since there was now no way to film the port side of the major model, and there was little reason to re-shoot a good library of stock footage, film of the older version was kept handy. While the smaller model was used occasionally in the series ("Tommorrow is Yesterday," "Requiem for Methuselah"), it was used mainly for publicity pictures with actors. Little stock footage of its original version was employed; however, both versions of the larger model found their way into every one of the following 78 episodes.

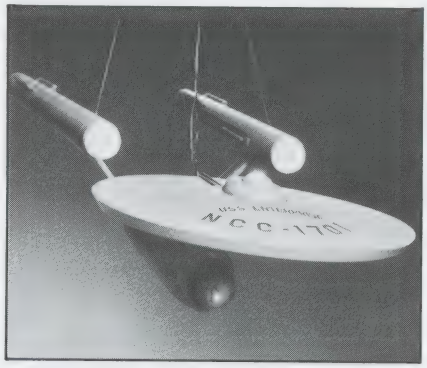
Perhaps the confusion that could be expected from these circumstances is at fault, but many of the drawings since published of the *Enterprise* contain inaccuracies.

With the exception of a tiny metal starship trinket created for the first segment of the second season, no more professional *Enterprise* miniatures were made. The second year did see several AMT model kits assembled to represent other starships in the episodes "The Doomsday Machine" and "The Ultimate Computer." Only the most minor changes, like turning the underside saucer numbers around 180 degrees, were made in the large miniature for the rest of the show's life.

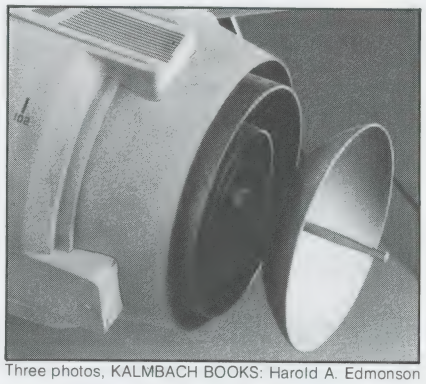
The producer managed to salvage the yard-long model when the show was canceled in 1969. Shoved into storage, the major *Enterprise* decayed until Paramount donated it to the Smithsonian Institution. Restored by adding new nacelle caps and a new main sensor screen, the *Enterprise* is now on display in the National Air and Space Museum.



Detail in the form of markings adds to the visual excitement of the secondary hull. The windows are gray and black, the stripes are red, and the underside markings are various colors (the circle is yellow outlined in red; the T is gray outlined in dark gray; the rectangle is white outlined in black; and the square is white outlined in red).

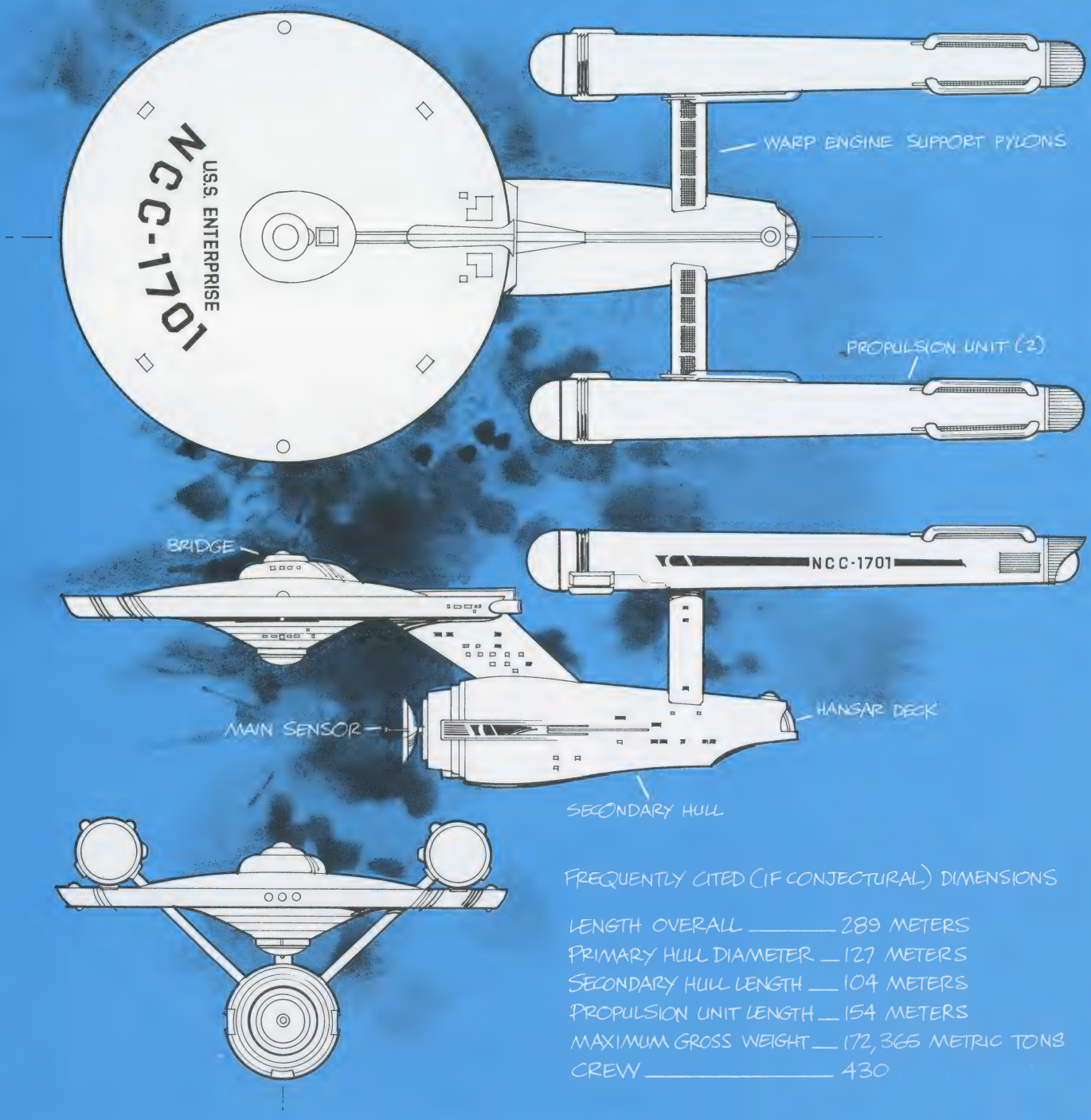


The Enterprise as it hangs in the Smithsonian today. Blinking on-off lights in the new red nacelle front end caps have replaced the "pulsating" warp drive lights of the television series.



Three photos, KALMBACH BOOKS: Harold A. Edmonson

Close-up view of the main sensor dish on the secondary hull, an item that was lost or destroyed after filming of the TV series, and had to be fabricated new during restoration. The dish is painted copper color.



FREQUENTLY CITED (IF CONJECTURAL) DIMENSIONS

LENGTH OVERALL	289 METERS
PRIMARY HULL DIAMETER	127 METERS
SECONDARY HULL LENGTH	104 METERS
PROPULSION UNIT LENGTH	154 METERS
MAXIMUM GROSS WEIGHT	172,365 METRIC TONS
CREW	430

Decaling—a most rewarding Enterprise

KIT: U.S.S. Enterprise from *Star Trek*
MANUFACTURER: AMT, U.S.A., Kit No. S951
SCALE: Unstated; based on the most often postulated prototype length of 947 feet, the scale would be approximately 1/636
DIMENSIONS: Length overall — 17 7/8"; Primary hull diameter — 7 7/8".

Don Klein

THE AMT *Enterprise* assembles quickly and easily, with only a modest amount of putty work. Decaling, however, is such an important part of building this model that the decal application technique described here is used to illustrate methods appropriate for all models.

After seam filling and sanding, which had to be done with extra care because of the extreme brittleness of the plastic in this kit, I replaced the sanded-away windows with .040" sheet styrene cut into 1/16" by 1/8" rectangles.

Mine is essentially a TV watcher's model, so I airbrushed the *Enterprise* Humbrol underside white, because that is the color the ship appears on my television. I then sprayed Floquil gunmetal over the outside of the nacelle end caps after the balls had been masked to protect the underside white.

The warp-drive domes at the front of the nacelles were sprayed Pactra brick red. The main sensor dish was painted copper; the backside of the dish and front of the secondary fuselage were painted flat black. I used a No. 000 brush to apply Pactra tinting black to the raised sheet-styrene windows. Tinting black was also used on the strut, nacelle, and intercooler screens.

The model was now ready for decaling.

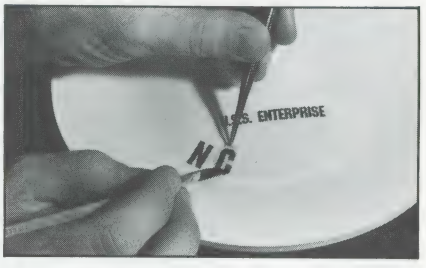
The surface of the model must be clean, dry, and free of oils, fingerprints, or other contaminants. **Use small pointed scissors (embroidery or nail scissors) to trim**

the clear decal film close to the printed lettering and designs. The main object of our decaling technique is to de-emphasize and hide this film, so trim it back as much as possible.

The success you have with the decals can also depend on the paint you are using. Decals adhere far better to a smooth finish (gloss paints) than they do to a rough finish (flat paints). If you have painted a model with flats, you might want to apply a coat of a clear gloss over all of the model. I gave the *Enterprise*, which I painted in flats, a heavy coat of Micro Gloss prior to decal application.

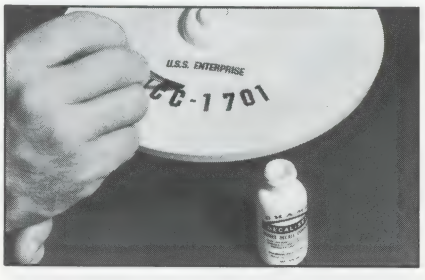
Place the decal pieces, one at a time, in a shallow dish of lukewarm water to soak

the film from the backing sheet. The decal is ready to be applied when it slides freely on the backing sheet, usually after 10 or 20 seconds of soaking. Use tweezers to place the decal and backing paper on a clean paper towel to drain off excess moisture. **Position the decal on the model, and gently slide the backing paper out from**



under it. Carefully adjust the position of the decal by gentle prodding with the tip of a watercolor brush, and blot up all remaining water with the corner of a paper towel. Gently press the decal against the model surface with your fingertips, and try to work air bubbles out from the center of the film to the edges.

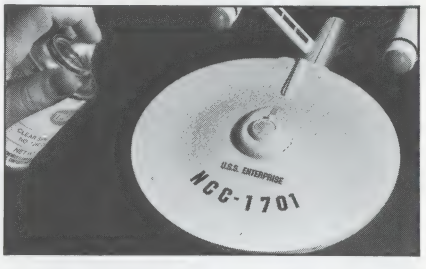
Next, apply decal setting solution. There are several brands, but all are solvents that soften the decal carrier film and allow it to conform to the model. Be sure to use the brand recommended by the manufacturer. **Brush on the first application of setting**



solution, and leave the decal alone while it works. Because of the raised panel lines on the *Enterprise*, I even brushed a drop of setting solution on the surface of the painted plastic before I laid down the decal.

When dry, use a needle to prick any bubbles in the film, then brush on more setting agent. Repeat this process until the decal hugs the surface perfectly.

Give a model at least overnight to dry, then apply a clear flat coating to further



hide the edges of the decal film and protect the lettering during handling. Any of the commercial clear flat products are suitable, including Floquil flat finish, Pactra clear flat, Scalecoat flat glaze, and Testors Dullcote. Several of these coatings are available in spray cans.

The ultimate starship

ALTERNATE MARKINGS: More accurate markings are available from Estes Industries, Penrose, CO 81240. Ask for U.S.S. Enterprise decal, part No. PN 37078. Enclose $1.75, which includes postage and handling.

Richard Van Treuren

ALTHOUGH several different models have been offered over the years, we will limit our discussion to making accurate models of the pilot-film and production versions of the *Enterprise* from the AMT kit. Overall, this kit is an excellent miniature, and in one sense, it is absolutely accurate because several of the kits were assembled, damaged, and used in second-season episodes.

Unless you have an older (large box) AMT kit, you'll need an Estes *Enterprise* rocket kit for the decals because the more recent (small box) AMT kit includes inaccurate markings.

Before you start on the model, examine your reference material. Disregard photos of the smaller yard-long model (usually identifiable by the sky backdrop). Use photos of the 11-foot model as your guide, including those presented here, and ignore all but the corrected drawings that appear in this book. I've found that the best available references on the *Enterprise* are film clips of the model in the studio and publicity pictures taken just after the model was modified in 1966.

Some small inaccuracies in the AMT kit are virtually impossible to correct — the slight taper of the nacelles is not duplicated in the kit, for instance, and it would be very difficult to add. Depending on which version — pilot-film or production — of the *Enterprise* you choose, there are several things that will greatly add to the accuracy of your AMT-based miniature.

Regardless of the version you choose, start by removing the raised grid lines on the top surface of the primary hull. The ribs are interesting detail, but the *Star Trek* original was a "smooth" spacecraft. The key to the job — which will take an hour or so — is a sharp hobby-knife blade. Work slowly, and use a No. 10 X-acto blade to cut, peel, and scrape away the ribs. It's better to leave a little of the rib material to be sanded away than to dig the knife blade into the surface.

Sand the upper surface of the primary hull to remove the last traces of the grid. This is a small-scale model, so the finish must be nearly perfect to appear realistic. Start by wet-sanding with 400-grit wet-or-dry paper, and then use 600-grit paper, also wet. Inspect the surface frequently, using strong light from the side, and keep at it — this kind of work is mostly elbow grease. When you are satisified with the finish, prime the model, let dry, and dry-sand with Flex-I-Grit 8 micron silicon carbide sanding film. This should give you a very smooth surface for the final silver-gray paint coat.

Either version you choose to model also requires filling the three cup-like depressions on the underside of the primary hull. Next, add aircraft-type navigation lights: red on the port side, green on the starboard.

The most recent pressings of the model have omitted the navigational beacon at the top rear of the secondary hull. Any bubble-shaped item could be attached to form this beacon. You can make such a bubble by heating the tip of large-diameter sprue with matches until it melts to the proper shape. Saw the stem off flat, and cement the bubble in place.

Modeling the pilot-film version — If you decide to model the pilot-film starship, remove the cross-hatched, waffle-textured panels on the inner sides of the nacelle support pylons. Likewise, sand away the screening texture found in the inboard slots of the nacelles.

The main sensor screen on the pilot-film *Enterprise* was considerably larger than that on the AMT model. To enlarge it, add to the outer edge a 1/4"-wide gasket or a sheet-styrene ring, fill in the gaps with putty, and smooth to the proper contour. Trim the stem or enlarge the mounting hole so the screen can be drawn closer to the secondary hull.

Since the hangar bay was not a part of the ship until regular show production, remove the observation post atop the hangar-bay doors. The bridge section of the primary hull must be raised. A common fuseholder cap, available at any electronics parts store, fits well and can be sanded to the proper shape.

Carefully locate the center of each forward nacelle cap, drill, and add a small spike. An electronics store can provide electronic module gold turret terminals that will serve nicely here. Also, remove the globe-shaped portions of the rear nacelle end caps, and flatten those areas.

To finish the pilot-film version, use a satin, semigloss coating — not gloss, not flat. To be strictly accurate, the model should *not* be weathered. Decals from the Estes rocket kit can be trimmed and added to simulate many details on the pilot-film model. Don't forget to put the numbers for the underside of the hull on backwards.

The production Enterprise — Start on a production version of the starship by reducing the diameter of the main sensor screen about 1/8". As on the pilot-film model, the screen must be mounted close to the hull. Add raised dots made from pinheads to the flat forward ends of the inner intercoolers. If you have an older large-box kit, the globe-shaped nacelle end caps can be simulated with small marbles or large ball bearings.

The lip of the bridge cap must be filled in to enlarge it, but be careful not to increase the height of the bridge in doing so. After adding the navigation lights mentioned earlier, position smaller lights in line with them on the underside edge of the primary hull. As before, fill in the three cuplike depressions on the saucer underside.

Since the production *Enterprise* was subtly weathered, the model should be finished in a flat silver-gray. Here again, details from the Estes rocket decal sheet can be added to restore any raised details sanded away in the crack-filling and modification work. Finally, the numbers on the underside of the primary hull can be installed either forward or backward, since they were seen both ways during the run of the television program.

Kit conversion: Enterprise to Tug

Don Klein

ALTHOUGH the various styles and classes of United Federation spaceships derived from the *Enterprise* design are a creation of those who established a post-*Star Trek* mythology, the designs nevertheless can be intriguing to modelers wishing to engage in some simple kit conversions.

Publications such as the *Star Fleet Technical Manual* (Ballantine Books, 1975) show drawings for Destroyer, Scout, Dreadnought, and Transporter-Tug ships in addition to the Heavy Cruiser *(Enterprise)* configuration.

Any of these derivative designs can be built using the parts from the AMT *Enterprise* kit. I chose to build the Transporter-Tug, which meant that I would have to build a transport container in addition to the parts available in the kit.

For the transport container, I was able to obtain a length (7″) of 2 3/8″ acrylic tube. A length of 2 1/2″ plastic plumbing pipe should also work. Some of these items may be hard to locate, but you are free to choose your own materials (including household containers) that form a suitable cylinder.

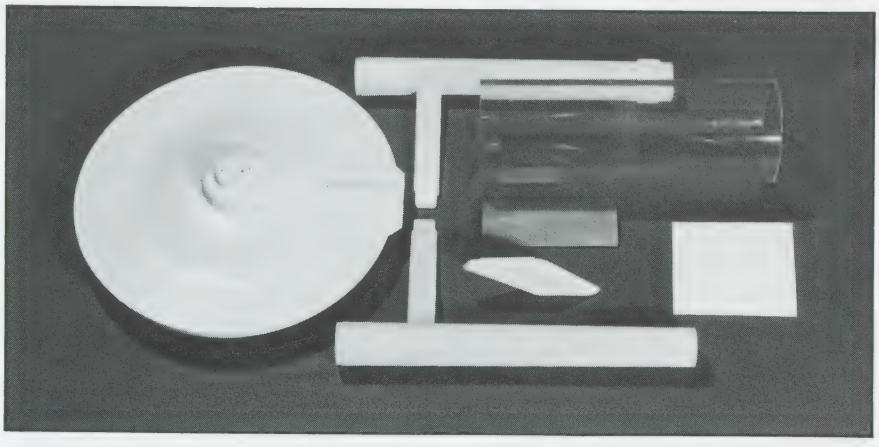
A big box of leftover parts from other plastic kits is almost an essential item if you plan to do many kit conversions, and my leftovers included bomb-bay doors from a 1/48-scale B-29. These would form the towing pad.

I spread the basic components out on the table to get a little better idea of what was needed and how everything would go together.

I began my work with the primary hull. The major change was that I discarded the bottom dome and added a support for the main sensor. In place of the dome, I cemented a thin plastic disc, then extended a 20mm gun barrel (almost any polelike piece will do) from Monogram's Panzerspähwagen eight-wheeled armored car. Using ACC adhesive, I placed a beebee at the end of the gun barrel and then attached the sensor dish (after cutting away a portion of its attaching peg) to the beebee, facing it forward.

The warp-drive propulsion units required a little more work. Because on the tug the units are supported by downward projecting pylons, I was able to simply reverse the positions — the kit's right propulsion unit became the left and the left became the right. The intercoolers, however, still had to be moved to the top of the warp drives. The unneeded location holes were filled with sprue and sanded over. The attaching pegs on the intercoolers were removed, and the units were placed flush on top of the warp drives and cemented with Micro Weld.

The warp-drive pylons were attached directly to the bottom of the primary hull. In order to get the proper placement angle, I used a razor saw to cut off the tip of the pylons at a 45-degree angle. A piece of 1/16″ sheet styrene was cemented to the end of each pylon, allowed to dry, then filed and sanded to shape. Later the pylons were cemented in place.



Major components used in making the Tug were the saucer, nacelles, and central strut (sawed from the secondary hull) of the AMT kit, plus bomb-bay doors from a Monogram B-29, a length of acrylic tube, and sheet styrene for the tube ends.

The bomb-bay doors I used as the tow pad were placed over the acrylic tube and cemented so they would conform to the cylindrical shape.

I used .020″ sheet plastic to make the ends of the transport container. I placed the sheet plastic under a 3″ circle template and made a continuous cut with a heavy straight needle (not a straight pin) until the plastic was cut through. I made covers for each end, attaching them in place with ACC. The plastic cements would not have bonded to the acrylic tube securely enough to endure filing and sanding. After the sheet plastic was firmly secured, it was cut and filed to the contour of the tube.

The strut joining the primary hull to the towing pad was the same strut furnished in the kit, except that it had to be severed at the bottom where it was molded to the *Enterprise's* secondary hull.

I airbrushed the Transporter-Tug with a mixture of Pactra primer white and Pactra aero blue. I also gave it a coat of Micro Gloss heavily diluted with Micro Thinner, resulting in an even matte finish.

I used several decal sheets to come up with enough letters to form "Star Fleet Transport Command" on the sides of the container.

Shapes of good and evil from TV's Battlestar Galactica...

VIPER AND RAIDER

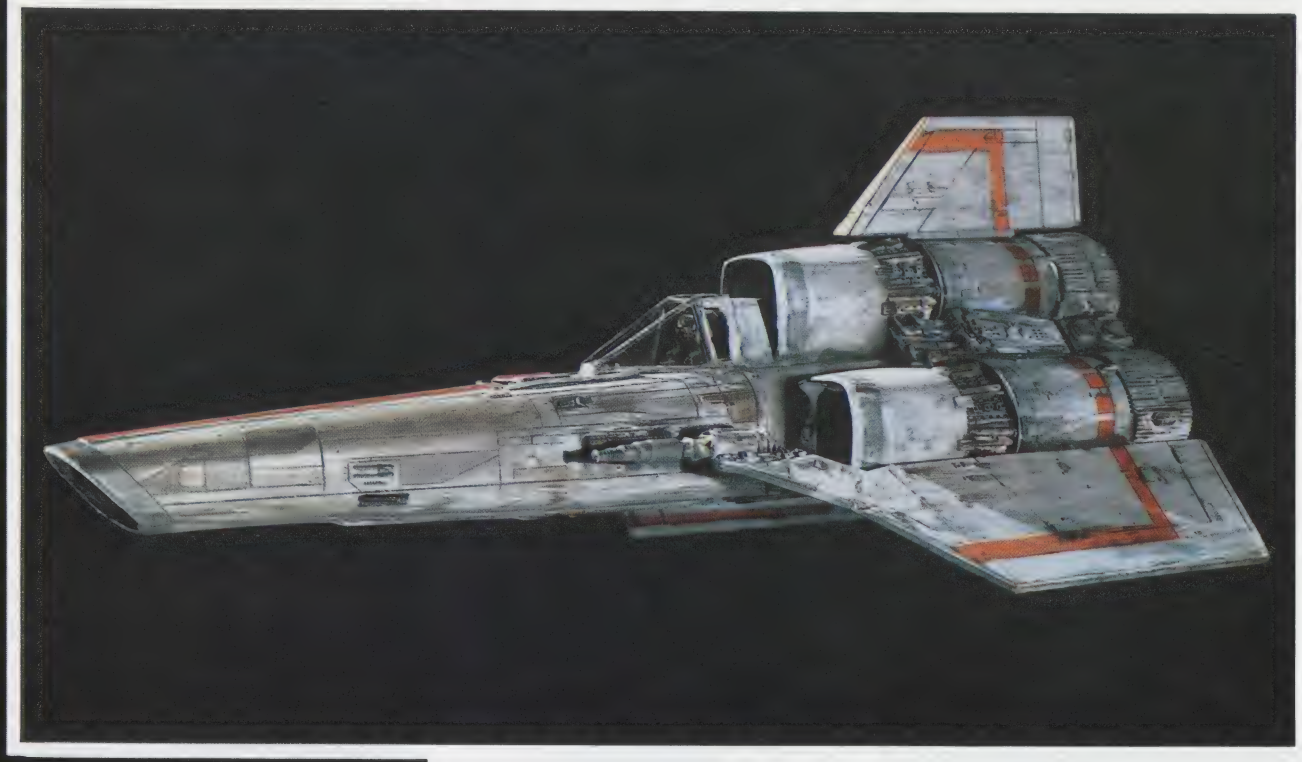
CHRIS TIETZ

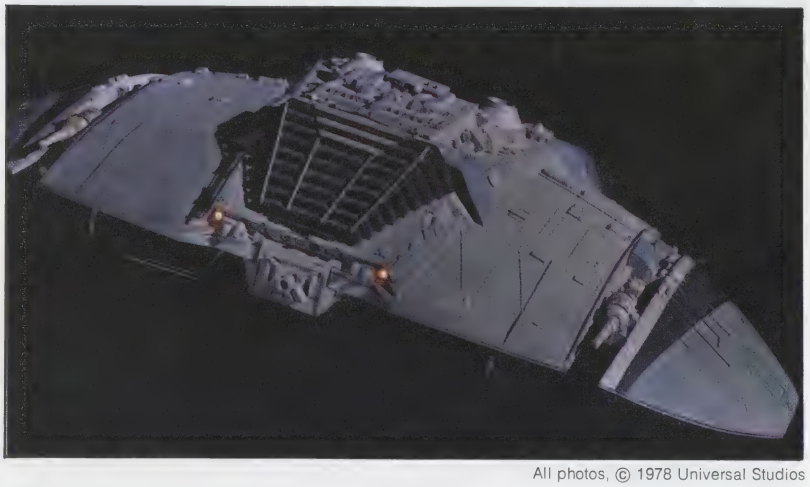
BATTLESTAR GALACTICA fills the television screen with action-packed derring-do among the distant stars, exposing audiences to new and exciting alien civilizations and technologies. Glen A. Larson is Executive Producer and creator of the series; Universal Television is the studio; and ABC-TV (which telecast the first story in the fall of 1978) is the network. The story revolves around a race of peaceful humanoids who are sneakily attacked by a rival race of armor-clad mechanical beings known as Cylons.

The peaceful race — which exists in twelve colonies on twelve planets — has unwillingly battled the Cylons for a thousand years. Weary of war, its Council of Twelve has finally negotiated a tentative peace agreement with the Cylon Empire. As they trustingly approach the Cylons in deep space with most of their combined worlds' spaceships, including enormous "Battlestars," the peace-seeking humanoids are betrayed, attacked, and virtually wiped out, as are their home planets. Only the *Galactica* ship, temporarily diverted from the main fleet, escapes destruction. Horrified, the *Galactica* crew helplessly observes the holocaust via long-range viewers.

When the *Galactica* ship returns to its home base, the outraged crew finds a burned-out world. Gathering together what's left of their belongings, that world's survivors begin a shaky Dunkirk-like exodus in a rag-tag fleet of spaceships, using any and all types of spaceworthy vehicles. These tattered remnants rendezvous with *Galactica,* and together embark on a long voyage in search of the legendary planet Earth, so they can hopefully establish roots on a new globe. This immense journey is punctuated by encounters with alien beings and hazardous space phenomena, and is underlined with anxiety over being caught by the ever-pursuing, always vicious Cylons.

The Galactica ——— The *Galactica* itself is a 2,000-





All photos, © 1978 Universal Studios

foot behemoth of a spaceship with a strikingly reptilian appearance. Its wedge-shaped bow cuts a domineering swath through space. Two huge rectangular pods straddle the center of its body in gigantic outrigger fashion. The twin pods serve as hangars for the ship's shuttlecrafts and its fleet of attack-intercepter Viper ships.

The Viper intercepter ——— These one-man intercepters are 29 feet long, with three fuel-burning rocket engines that have inner atmospheric flight-and-landing capabilities. They achieve extreme acceleration in space by use of turbo thrusters, and can throw themselves into an immediate reverse direction: a useful ability in battle situations. Twin laser guns are mounted along each side of the Viper's fuselage, just below the cockpit, jutting forward from the wing fronts. The hangar pods of the mother ship *Galactica* provide complete storage and maintenance facilities for the Vipers. A Viper is shot into space through one of 20 launch tubes lining the outward side of each pod. To re-enter a hangar, the small intercepters approach the rear of a pod and plunge through the landing bay door's gaping mouth — which is also the entrance/exit port for shuttlecrafts.

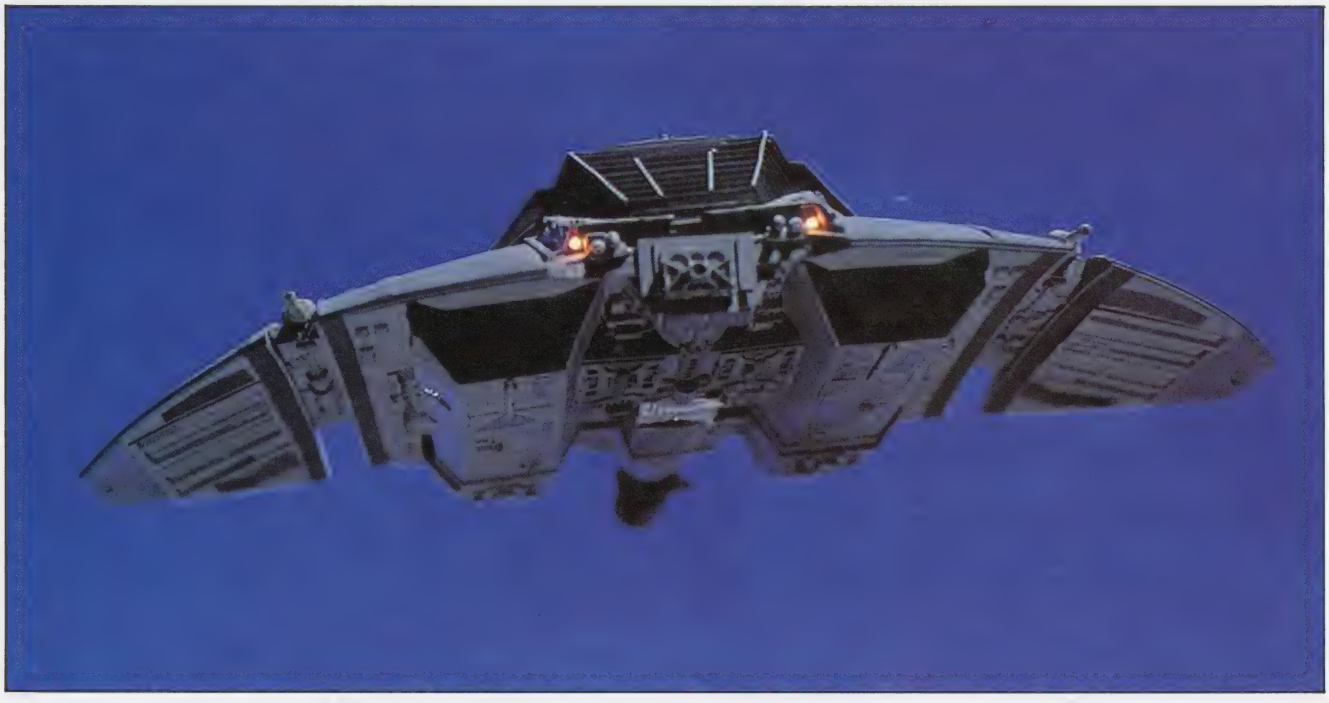
The Cylon attack ship ——— Ever appearing to menace our space travelers on their odyssey are the manta ray-like Cylon ships, with rounded wing shapes that curve down at the ends as if to encircle and engulf their prey. These inner/outer atmospheric, twin-engined, three-robot ships have twin-mounted laser guns, one on each side of their louvered cockpit shields, and are 35 feet wide by 26 feet long. The Cylon ships harbor themselves aboard their floating headquarters which is shaped like two huge saucers joined, and separated, by a thick central column. The entire configuration spins ominously through space in search of the fleeing humanoids, ever ready to launch its fleet of attack ships against *Galactica.*

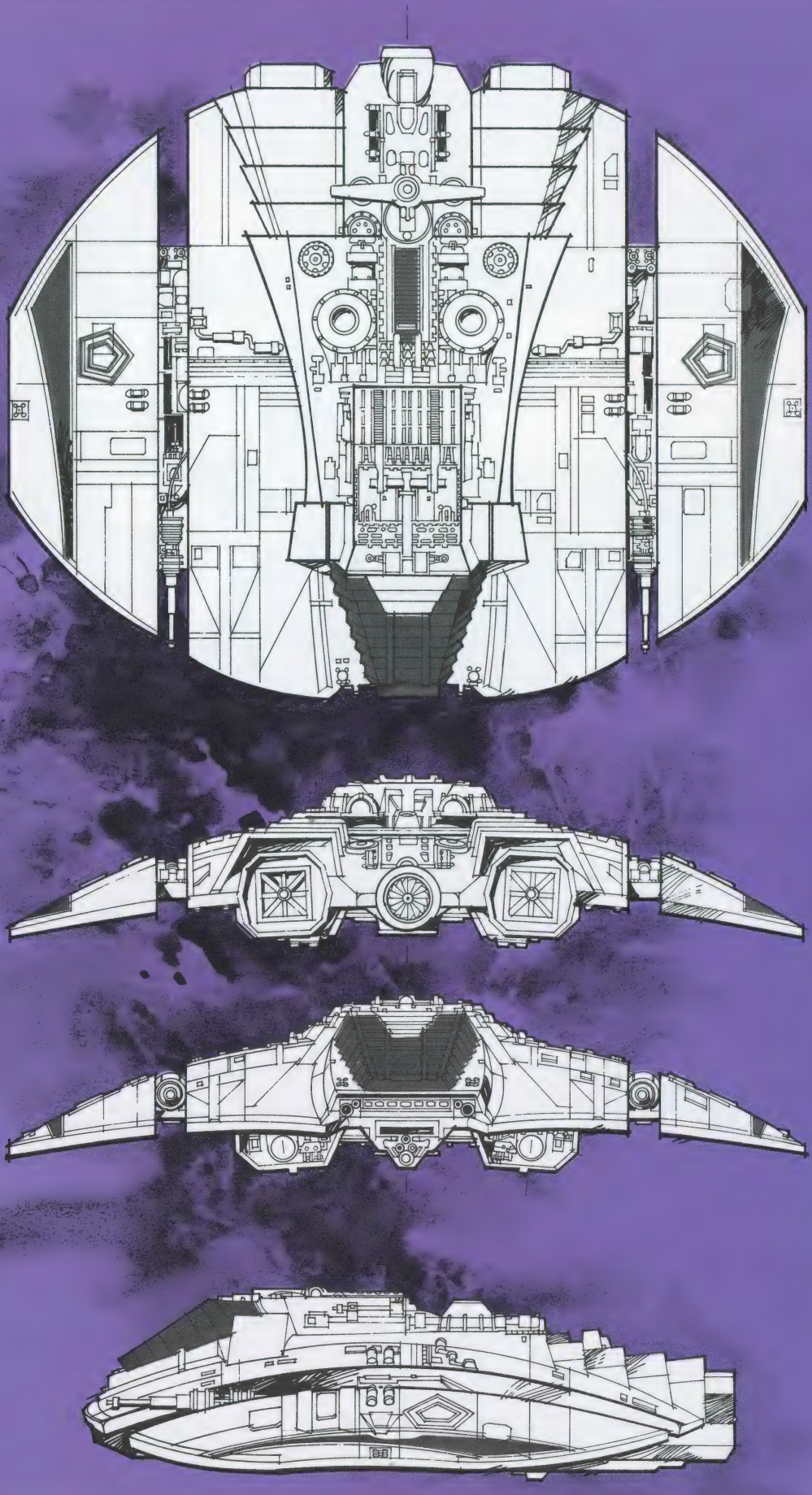
Both photos, © 1978 Universal Studios

THE 2,000-foot *Galactica* is actually a 6-foot-long model equipped with air-cooled quartz-light engines and dozens of tiny, glowing optical fibers that serve as viewports. Its surface is painstakingly detailed with cannibalized model-kit parts. Only one model exists. By means of multiple exposures shot from many different angles, it represents an entire fleet.

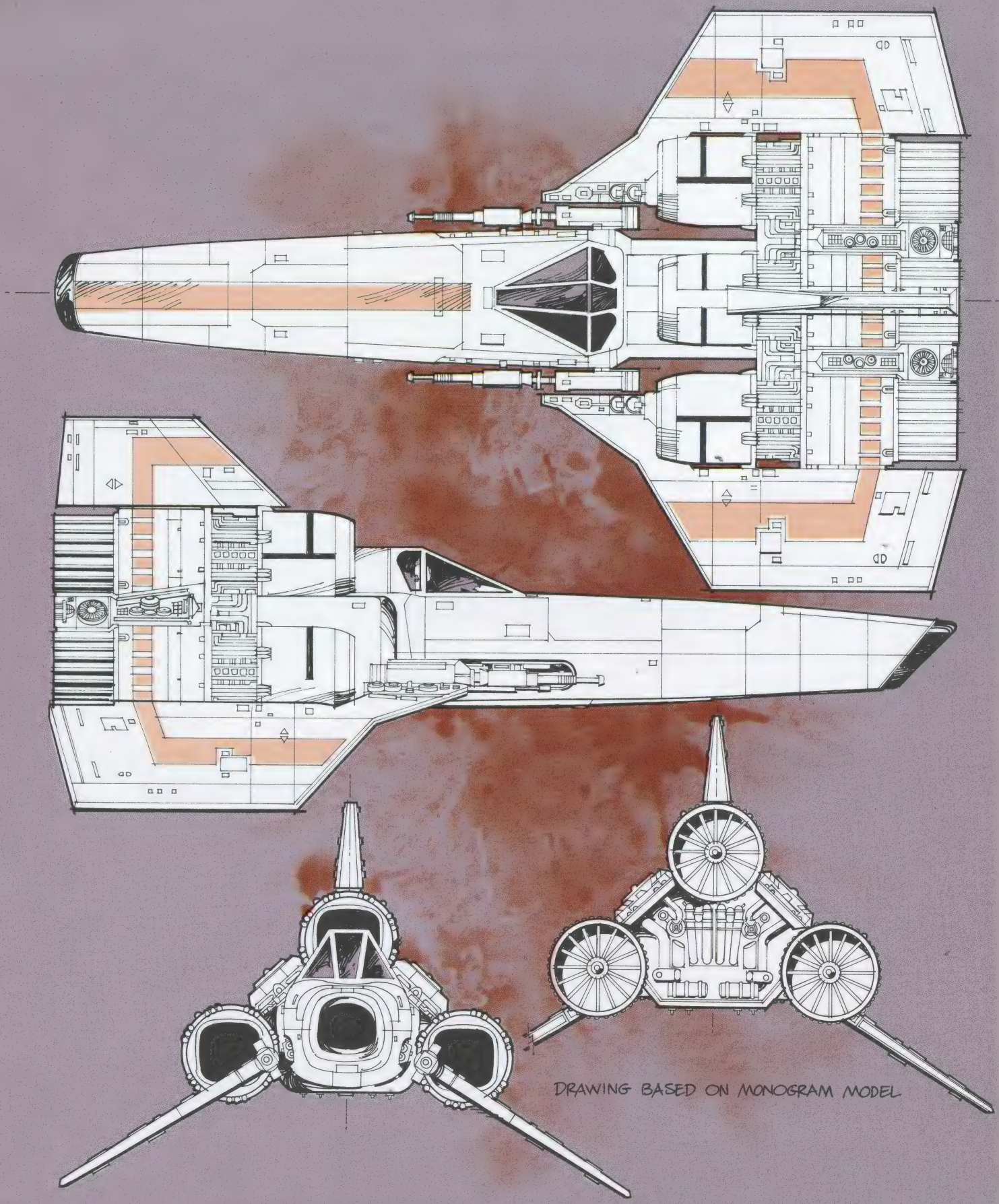
The Viper intercepter ships, built in 1:16 scale, are manufactured from a mold that produces six basic components forming one complete ship. Such ease of assembly permits rapid construction when models are needed. No explosion versions exist. Since all detonations are effected optically, models are never lost. Three of the Viper models are specially equipped with nitrogen "engines." Liquid nitrogen is injected into the airflow which passes around hot quartz lights, producing a showy vapor trail to indicate that turbo thrusters are operating. One Viper model is fitted with landing gear.

Like the Vipers, the bat-type Cylon ships are mold-made and feature air-cooled quartz-light engine effects. These models are built in 1:24 scale. Laser-gun effects for both types of ships are achieved optically. A full-size Viper intercepter ship is used in scenes with actors. Because of the greater dimensions of the Cylon ship—a result of upping the crew from one to three robots—only a full-size mock-up of its cockpit area was built.





DRAWINGS BASED ON MONOGRAM MODEL



DRAWING BASED ON MONOGRAM MODEL

Battle damage adds realism to Viper

KIT: Space Fighter Viper
MANUFACTURER: Monogram, U.S.A., Kit No. 6027
SCALE: Unstated; approximately 1/32
DIMENSIONS: Length — 11″; wingspan — $5^{13}/_{16}$″; height — $3^{15}/_{16}$″.

Bob Hayden

REALISM, not perfection, is what most of us strive for in scale model-building. Many modelers weather their models to add realistic evidence of use and age and to bring out detail. Battle damage on combatant models is part of weathering, and I built Monogram's excellent Viper kit specifically to try out some battle-damage techniques.

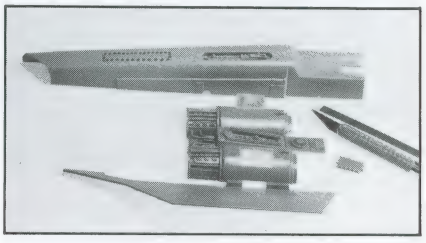
I built two Vipers. The first was built "stock" to acquaint myself with the kit, to identify any problem areas, and to determine the best assembly sequence for the damaged version. Although it certainly takes longer than just diving in, I recommend this "stock kit first" procedure any time you plan to modify a kit extensively. Before building either kit, I planned the damage I wanted to add. I found an easy way to record my ideas was to attach a sheet of tracing paper over the photo on the boxtop and doodle away. This way, you *make* your mistakes on paper, where they are easy to erase, and *check* your ideas against the unassembled model parts.

I decided to add only moderate battle damage to my model to represent a craft that had sustained two or three close laser-cannon hits, but that was still flyable. I also wanted to build the damaged version using only one kit (often, extensive modifications require a second kit to provide "fit-in" panels or hatches where holes are made in the first kit). I settled for the damage shown in the photos: a peeled-back sheet-metal panel on the left side of the fuselage near the nose, a blown-away access-hatch cover on the number two engine, and a skin rupture on the port wing.

Both models share the same basic paint scheme. The overall color is a light gray made by adding small amounts of silver to white. This gives you a color that has more "life" than a gray made by adding black to white. The fuselage nose fairing and the rear engine casings are a dark metallic gray, also with some silver mixed in. The striping was done using the kit decals.

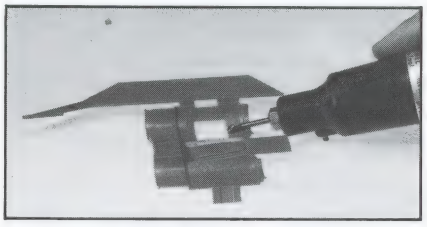
Let's get to the heart of the job — the battle damage treatment. Bear in mind the battle-damage techniques can also be used to add details such as open servicing hatches to undamaged models.

The first task was to remove the forward fuselage panel and the "blown away" hatch on the engine housing. Many modelers favor a jeweler's saw for this kind of cutting, but I find I can work faster by drilling many holes around the perimeter of the area to be removed. I used a $^{3}/_{32}$″ drill and left a $^{1}/_{64}$″ safety margin between the holes and the edge of the opening. **After drilling the holes, cut through the narrow bits of plastic connecting them, remove**



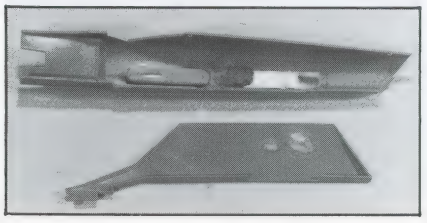
the waste material, and finish the edges of the opening with files. Work to the line slowly and carefully.

The full thickness of the plastic is much too great to simulate sheet metal, so **the next job is to remove material from the back of the parts to make the exposed**



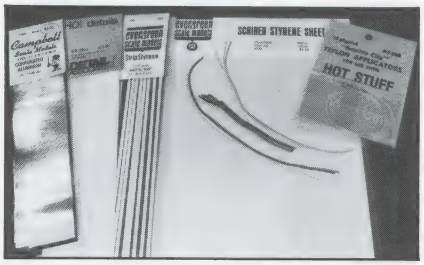
edges thin. I used a steel cutter in a motor tool to do this work. A slow-speed control is a must here — if the tool runs fast, it will melt the plastic instead of cutting it. I used a ball-shaped cutter. Here again, work slowly and carefully, removing only a little material at a time.

The peeled-back fuselage panel is made from .010″ styrene sheet. Cut a strip to the correct length and width to fit into the opening in the fuselage. Then, hold the strip over the barrel of a hot knife (a soldering iron will do the same job) to soften it. While the plastic is slightly rubbery, deform it as shown in the photos. **Next, cement it in place with Micro-Weld and smear 5-minute epoxy over the joint on the inside for strength.**



To make the impacted area on the wing, I slowly warmed — again, using the hot knife — an area on the underside of the top wing section until it sagged downward. I allowed this sunken area to cool and used the ball cutter in the motor tool to cut through the plastic from beneath. The ragged hole that this makes does a good job of representing a glancing laser-cannon impact.

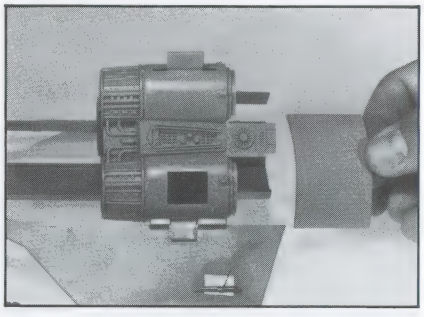
Before we can start assembly, we need to settle on the inner structure that will show through the damaged openings. The small hole in the wing is the easiest. **I backed the hole with a small scrap of corrugated aluminum siding — the kind**



sold for model railroad structures — and added three sizes of wire to represent cables and hydraulic lines. I painted this green to contrast with the wing color.

The peeled panel in the fuselage is backed with 70-mesh brass screen painted light blue. To this I glued several sizes of small wire and two pieces of small-diameter stranded insulated wire to represent a ruptured cable. A few small rectangular styrene pieces represent electrical junction boxes and instrument sensors.

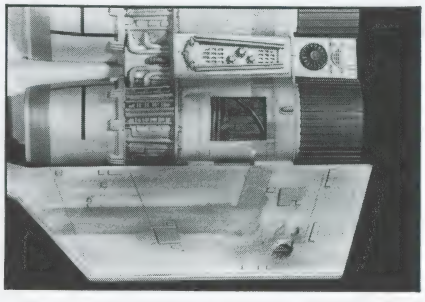
To back the blown-away engine service hatch, I cut a piece of scribed styrene to fit



inside the engine housing and pre-curved it by rolling it around a ¾″ dowel. Next, I painted it orange and added another stranded-wire ruptured cable, two clear fuel lines (made from the Teflon tubing that comes with Hot Stuff brand ACC), a piece of wire, and three junction boxes.

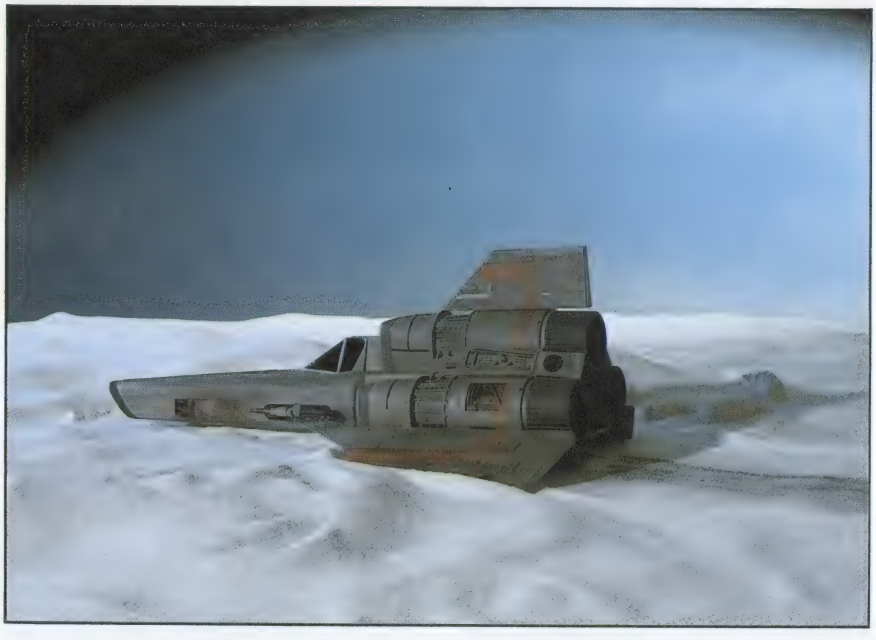
I then removed the inserts and sprayed the inside of the fuselage flat black to ensure that any light that gets into the model

will not reveal the lack of complete detail. **I assembled, painted, and decaled the model using standard kitbuilding procedures, being careful to maintain open-**



ings through which I could position the battle-damage inserts. I added the inserts during final assembly.

One item that is lacking in the kit is a black decal piece for the small cockpit window pane on the top surface of the cockpit. I made one by cutting the correct shape out of a scrap decal. To keep the window panes shiny while spraying the rest of the model with clear flat finish, I cut individual masks from Scotch Magic Transparent Tape and lightly pressed them over each window area. After applying the flat finish and pastel-chalk weathering, I removed the tape, revealing the glossy areas.



Other modifications that come to mind for the Viper fighter include replacing the opaque cockpit windows with clear plastic, adding cockpit detail, and adding skilike landing skids. The best bet for landing gear would be to utilize strut parts from an aircraft model and make the skids from sprue.

Fiber optics light the Raider

KIT: Space Fighter Raider
MANUFACTURER: Monogram, U.S.A., Kit No. 6026
SCALE: Unstated; approximately 1/35
DIMENSIONS: Length — $8^{13}/_{16}$"; wingspan — $10^{11}/_{16}$"; height — $2^{13}/_{16}$".

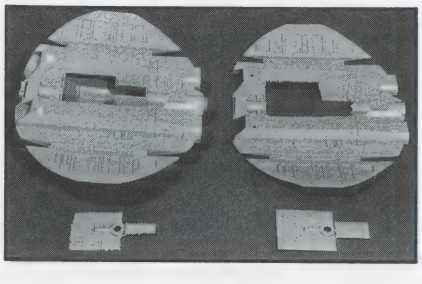
Bob Hayden

MONOGRAM'S kit of the evil-looking Cylon Raider fighter from *Battlestar: Galactica* captures the basic forms and intricate detail of the original, but a major problem is the poor fit of the fuselage sections. These are very large injection-molded pieces — almost 11 x $8^{1}/_{2}$" — and they don't mate well. In fact, both sections must be flexed considerably to get them to mate at all. The instructions, which are structured around the working missile launchers, depict the fuselage halves going together last. This sequence of assembly is almost unthinkable for scale model construction, because we want to fit, putty, and finish the major fuselage joints early-on in the assembly job.

Because of the filling, filing, and sanding time required, I did not assemble the model with major modifications or detailing, but I did add a moderate amount of fiber-optic lighting.

In cutting an access opening for the fiber-optic lighting system, I substantially increased the flexibility of the bottom fuselage section. This, in turn, made mating the sections easier and also allowed join-line filling before the addition of the lighting system.

Making the access hatch — The slide-out opening that I devised is similar to many portable-radio and tape-player battery compartments. Building this feature required two Monogram kits: one to furnish the bottom section into which the opening was cut, and one to provide the hatch. **Start work on one of the unassembled kit sections by drilling several dozen**



holes around the periphery of the "hatch" piece in the bottom. Use a fine jeweler's saw to cut through the plastic between the holes, and remove the hatch. Carefully finish the edges with a medium-cut file.

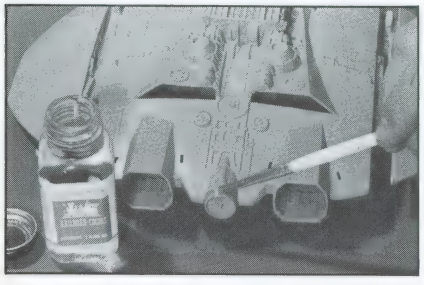
Next, drill holes in the bottom section that will be used on the finished model. Stay inside the hatch area with your drilling, and, again, connect the holes by sawing. Carefully file the edges of the opening smooth, checking the fit frequently with the hatch. Cement styrene strips in place to make retaining slides for the main section of the hatch, then fabricate and install the hold-down cam-tongue arrangement for the narrow rear portion of the hatch.

Discard the working rocket launchers entirely — they complicate assembly, the action feature is of little value, and the TV craft do not launch similar ordnance. Cover the front launcher holes with round plugs made from the tips of the missiles, and add short sections of styrene strip to cover the actuator holes on the bottom of the craft.

Fuselage assembly - Next, assemble the fuselage halves. I bonded one area at a time. First, bond one side "wing" area, and allow overnight setting. Then, bond the central sections; again, allow overnight drying. Finally, bond the remaining "wing." This approach permits stressing of the parts into proper alignment while using a limited number of clothespins and spring-action clips.

You'll find many places where the fuselage halves don't come together in a smooth edge. Use a file to make the majority of these areas presentable, but resort to filler putty in some spots, notably around the front of the cockpit area and around the engine exhaust ports. The rear central fan housing also requires a built-up ring of putty to properly fair it into the rear of the fuselage.

After completing the putty work and wet sanding all refinished areas with 400- and 600-grit paper, **I coated all puttied areas with Floquil Barrier. This prevents the**

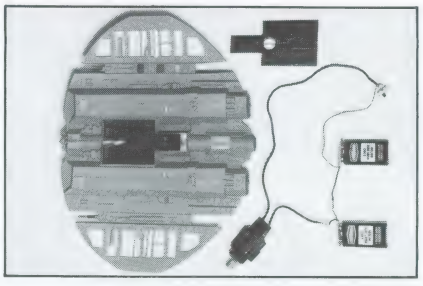


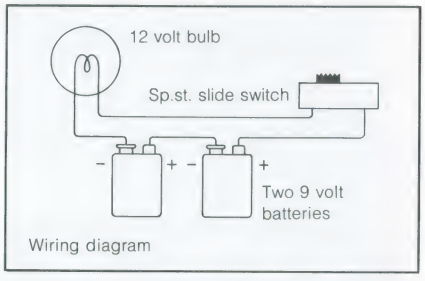
solvent in the paint or primer coat from softening the surface of the filler putty. Often, a paint such as Floquil, even when applied almost "dry" by airbrush, will soften filler putty. When the putty dries, it will shrink just a little, opening cracks around its edges. The Barrier coat defeats this tendency.

At this point I added the rest of the kit parts. I also cut plugs from heavy sheet styrene and added them to the exhaust ports, then cemented the exhaust-port inserts — part 11 — to this plug. This simple modification blocks the interior from view, making the model appear more substantial and realistic.

The lighting system — Before any painting, I worked out the details of the lighting installation. Adding lighting to a plastic model, especially a small-or medium-size one, involves a tradeoff. On one hand, the finished effect is usually excellent, but on the other, there are many problems: added weight, access to the components, heat buildup inside the model, and light leaks. All these problems take time to solve, and you should realize that including even simple illumination effects will take a good deal longer than building a "straight" model.

I decided on fiber-optic lighting for the Raider model for several reasons. First, and most important, fiber-optic light guides allow you to use a single light source — one bulb — to take light to more than one location. This cuts down on heat buildup inside the model, and it also means that there is only one bulb to burn out — and to replace. Finally, using only one bulb means that there is only one source of light leaks to seal off. The fiber-optic light guides and light source that I used are sold by The Hobby Factory, P.O. Box 67, Abington, PA 19001. I used their No. 40 hobbyist kit, which provided several sizes of light guides, a 12-volt focused light source, and colored dyes.





Wiring diagram

Accomplishing as much pre-installation work for the lighting system as possible before doing any painting prevents the model from becoming worn and dog-eared from the handling during lighting installation. After deciding where I would place the individual lighting elements, I drilled holes for each and checked the fibers for fit. I then made a lens on the end of each fiber by holding a lighted match near it as described in the instructions. After once again checking for fit, I removed the fibers, labeled them as to location, and dyed the ends. I also assembled and checked the light source and batteries for fit inside the model.

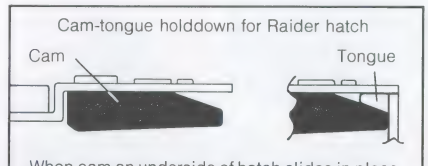
With all holes drilled and the groundwork for the lighting installation complete, I airbrushed the inside of the model with flat black enamel to minimize reflections. I then airbrushed the exterior with a dark metallic gray made by mixing a small amount of Floquil platinum mist into stock reefer gray.

I applied Floquil Crystal-Cote on the areas where the decals were to go and then applied the decals. I spent one evening picking out raised panels and details with a slightly contrasting metallic gray flat enamel. I also used other colors — black, red, deep blue, and bright silver — to pick out raised details and add a three-dimensional quality to the model. The recessed panels on the underside of the craft were painted off-white.

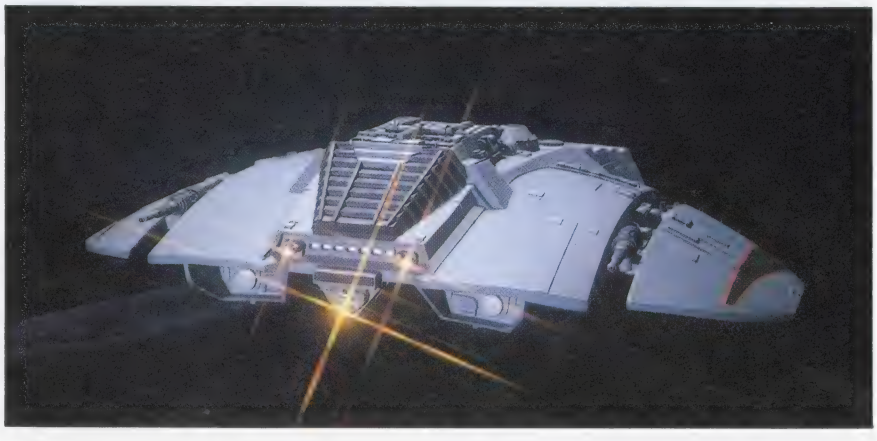
When I was satisfied with the paint scheme, I airbrushed the entire model with Testors Dullcote. This coating is available only in spray cans, so in order to airbrush it you have to discharge the can into a bottle! This may seem like a very uneconomical way to do the job, but the Dullcote is a very good matte finish and well worth the extra step and extra expense.

Final lighting installation — Adding the lighting completes the job. I wired the light source to two 9-volt transistor radio batteries in series, giving a theoretical 18 volts. The actual voltage is more on the order of 14 volts, which will not blow out the automobile bulb in the light source. I modified the light source by cutting back the conical end housing and epoxying a short piece of $^3/_8$" o.d. brass tubing in place. This makes it possible to gather together and illuminate a larger bundle of light guides. I found that the fiber bundle I made would fit into a piece of $^1/_4$" o.d. tubing, so I used three short sections of the intermediate tubing sizes to bush the bundle up to a slip-fit into the tubing section on the light source. These telescoping tubing sizes — available at almost every hobby shop — are handy for many projects. In this case, they allow removal of the light source from the model for bulb replacement but maintain good alignment of the light source and light guides while in the model.

Touch up the sides of the light guides where they are external to the hull of the ship. That done, drop in the light source and batteries, push the switch to "on," and turn out the room lights to get the full effect of the lighted miniature.



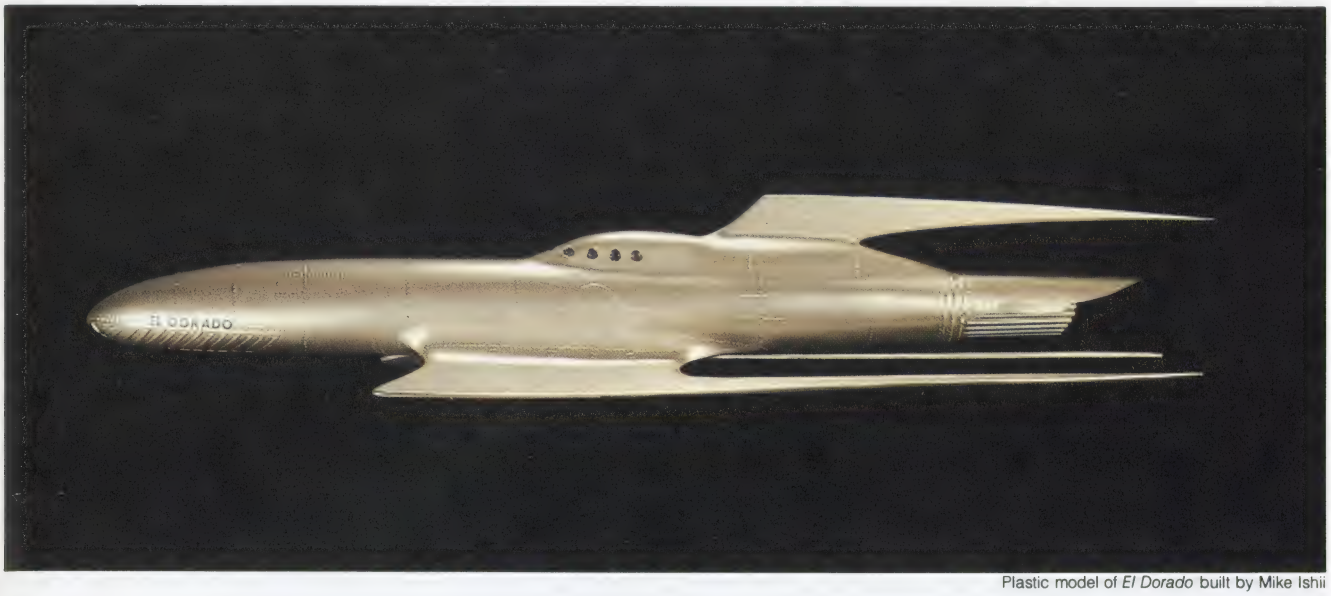
When cam on underside of hatch slides in place, tongue forces it down tight. Both cam and tongue are made from heavy (.060-.080) sheet styrene



BUCK ROGERS IN THE 25TH CENTURY
BY DICK CALKINS & RICK YAGER
AND - AS THE FIRST GOLDEN SHAFTS OF DAWN BURST FORTH TO FLOOD THE SCENE, THE EARTHMEN STAND IN SILENT AWE AT BREATH-TAKING BEAUTY SUCH AS NO SPACE-FARING MAN HAS EVER BEFORE WITNESSED
EL DORADO
WHEW!! WHAT AN EYEFUL!
HEH! SHH.... THE KING IS ABOUT TO SPEAK!
SPACE SHIP "EL DORADO".... I, KING OF LLORE, ENTRUST TO YOU THE HONORED TASK OF SAFELY CARRYING THESE EARTHMEN, STRAIGHT AS A SUN-SHAFT ON THEIR HOMEWARD COURSE!
EARTH FRIENDS, MAY YOUR JOURNEY BE SWIFT, PLEASANT AND WITHOUT UNFORSEEN EVENT! CARRY ON!
I DON'T KNOW ALL OF YOUR CUSTOMS, PRINCESS.. BUT THIS IS ONE OF OURS! SO LONG!
OH... BUDDY.. I... YOU... YOU... MFFF...
GOOD BYE, KING! WE ONLY HOPE THAT SOMEDAY WE CAN RETURN YOUR KINDNESS!
FAREWELL, FRIENDS!
GOODBYE AGAIN, PRINCESS!
BUT NOT FOREVER, BUDDY... 'BYE!
HER TREMENDOUS ROCKET MOTORS PURRING LIKE SOME SLEEK AND POWERFUL CAT, THE S.S. EL DORADO STREAKS FORWARD AS THOUGH ALIVE -- AND EAGER TO PROVE HERSELF WORTHY OF HER APPOINTED TASK -

By permission of Robert C. Dille; collection of Eugene Seger

The S.S. El Dorado made its comic-strip debut in March 1945. During the 16 months in which the ship was featured, various capabilities emerged: A speed of 11,612 miles-per-minute was portrayed as approaching "the danger point." At this speed, the crewmen had to "set the cosmic-repellor to clear a path 1,000 miles ahead." "A collision with even a small object could make a derelict of the El Dorado." Artist's license even prevailed: Later strips revealed a growth in size and a change of shape for El Dorado, with the cockpit moved forward and the fins filled out with more solid area and less of the spindly "rattail" extension. Not changed: the riveted, boiler-plate construction. Comic-strip classic notwithstanding, El Dorado apparently never did reach earth, but suffered an ignominious fate. When last seen it had been locked to the surface of the moon Tantoris by a magnetic ray. Although its crew escaped (after having saved the planet earth), using a form of flying belt, the hapless El Dorado was presumably lost when Tantoris was destroyed by a barrier of solidified air sent out by Mercurian scientists to prevent the onrushing moon from colliding with that planet.



Plastic model of *El Dorado* built by Mike Ishii

Buck Rogers' classic rocketship of gold

EL DORADO

RICK YAGER

OF ALL the hundreds of rocketships I created in 25 years of writing and drawing the classic adventure strip *Buck Rogers in the 25th Century*, none brought more mail response or comment than the great solid gold ship named *El Dorado* (land of gold).

The inspiration for the gold rocketship came as a result of an adventure Buck Rogers and his sidekicks, Dr. Huer, Barney, and Buddy, became embroiled in on the distant planet of Llore. They were informed by the friendly king that a vast treasure of gold coins was buried within the Mountain of Vanishing Souls.The king outfitted the earthmen with the mining equipment needed for a treasure hunt that, if successful, would enable Buck Rogers to "start planning the super rocket patrol ship I'm going to build for earth's fleet."

The earthmen not only had to locate and excavate the gold, but also had to keep it from the grasp of the evil Dr. Niarb, whose brain resided in the head of a robot. And they had to fight off vacuum-men, local mountain inhabitants with suction-cup hands and feet, who had no desire for gold but a persistent desire to capture Buck Rogers and his crew.

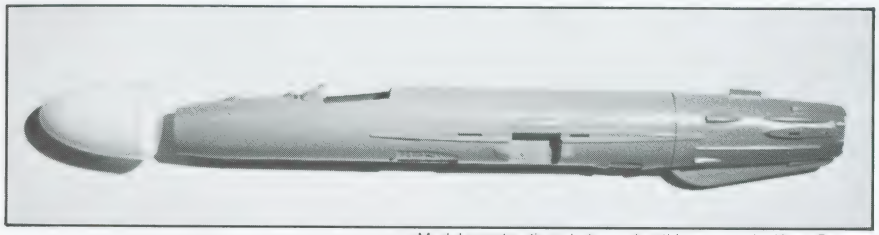
Successful at last, the earthmen returned to the kingdom and began several weeks of welcome idleness (during which crewman Buddy paid proper attention to Princess Llola). Soon the king announced, "Your gold, as deadweight cargo, would call for a ponderous freight ship—so I took certain liberties. I hope you'll approve."

The result was the S. S. *El Dorado*, fashioned by the king's men from the earthmen's share of the gold treasure. To discourage space bandits, the king had installed "super deathray guns . . . gyro-blastic vacuum artillery and magnetic-flash electronic pulverizers." The ship was slowed for landing by a battery of force-rays mounted on the underside. These were concealed behind vents that folded back in place (to complete the streamlining) when the force-rays were not in use.

As the ship approached earth, word was received that a wayward moon, Tantoris, was being directed by a "magno-atomic beam" from Mercury to collide with earth. *El Dorado* landed on Tantoris so Dr. Huer could adjust the receiving unit and reverse the moon's direction. But as the gold ship tried to lift off, a magnetic beam aimed by the angry Mercurians held it to the moon's surface. The episode drew much mail, the essence of which was contained in a letter from a bank president: "Don't you know that gold is non-magnetic?" He was right (who should know better than a banker?) But adventure strippers are not to be outdone by mere bank presidents, so I replied, "Dear Sir. I agree that a non-magnetic golden ship could not be held to its departure point by a magnetic ray . . . on *planet earth.* But earth rules do not apply to gold from Llore. On Llore gold *is* magnetic!"

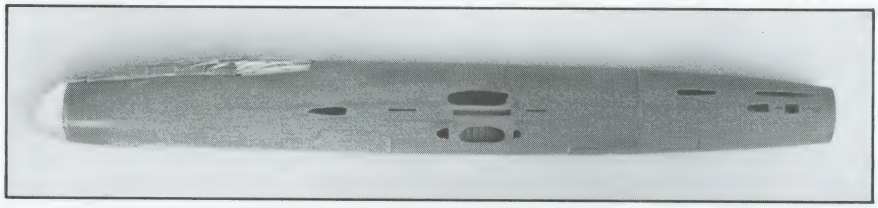
Mig+putty+styrene=El Dorado

Mike Ishii

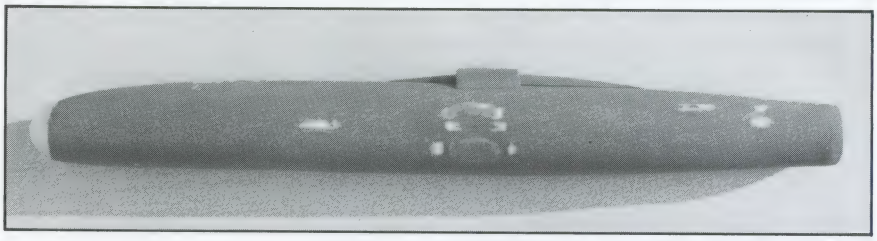


Model construction photography, this page only, Kerry Brunner

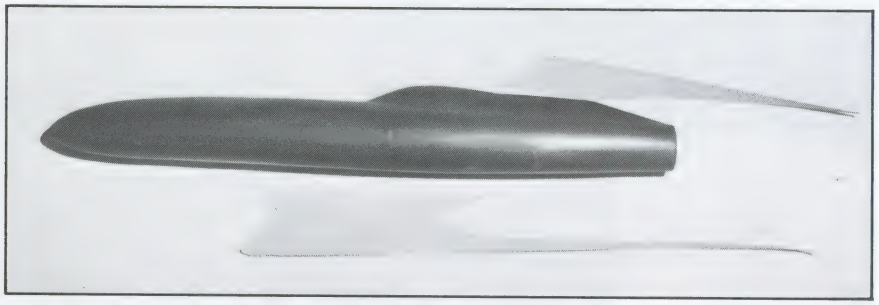
The basis for my model of the El Dorado was Revell's 1/32-scale Mig-21 PF (Kit No. H-267) and a separately available styrene model rocket nose cone.



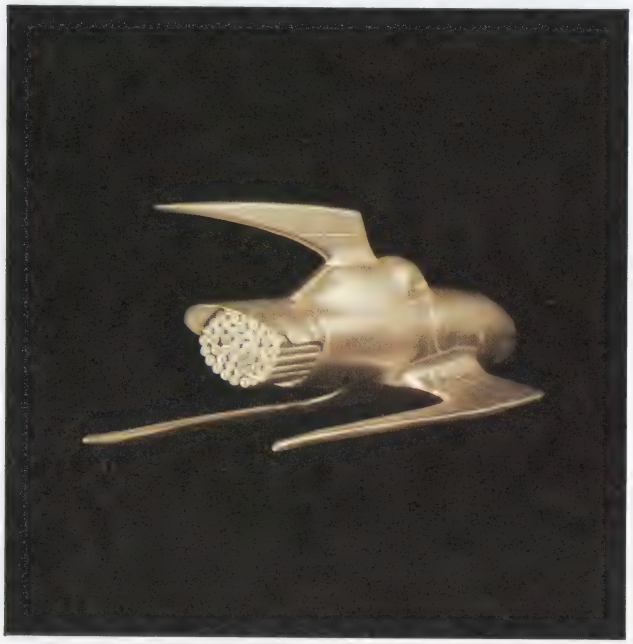
I used plenty of Weld-On #3 on the fuselage assembly so it would withstand sanding. The tip of the nose was sawed off to fit the diameter of the fuselage. I cemented the bay doors on but cut away protrusions such as wing roots and fins. I added pieces of sheet styrene over the cockpit area.

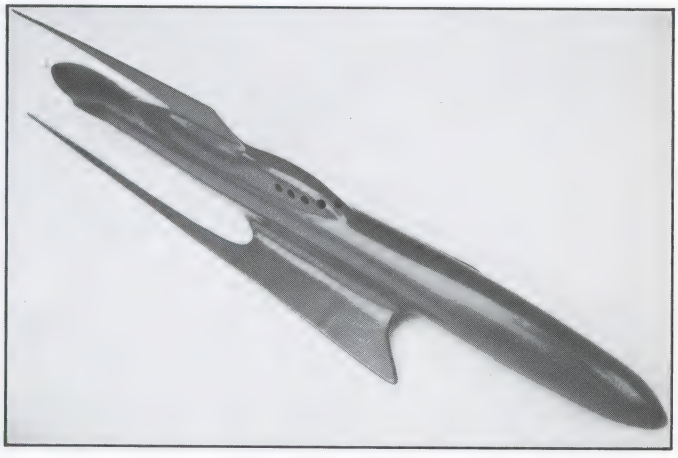


I filled the remaining fuselage holes with assorted pieces of styrene, then completed the filling process with Green Putty. Parts of the kit's fuel tank and dorsal fairing formed the basis for the canopy. Heavy sanding was required at all stages of construction.



Duratite Surfacing Putty, applied in layers, was used to refine the shape of the nose tip and to build up the canopy. The model was sprayed with aerosol automotive lacquer primer and wet-sanded with No. 400 and No. 600 sandpaper. I test-fitted cardboard fins which served as templates for fins cut from laminations (two sheets for the tail, three for the wings) of .040″ sheet styrene.





The fins were joined with ACC and filleted with Duratite. The canopy portholes were "drilled" with an X-acto knife and soldering iron. Sheet plastic (.010″) formed the tail cone.

Plastruct tubing formed engine pipes; .010″ strips made the nose vents. "Riveting" was done with hobby knife. Model was airbrushed with Testors No. 1144 gold, lettered with dry transfers.

GALACTIC GLOSSARY

GEORGE ELRICK

Attitude: Used when referring to a spacecraft's orientation regarding its forward direction and a frame of reference, such as a planet's surface. A positive attitude needs no correction. A negative attitude indicates an undesirable pitch, roll, or yaw. Pitch is rotation about an axis perpendicular to the vehicle's length and horizontal with respect to a celestial body. Roll is rotation about a longitudinal axis. Yaw is rotation about a vertical axis. The ability of a spaceship to maintain a desired posture is known as directional or weathercock stability and is normally brought about through the use of steering jets or rockets.

Braking ellipses: When a spacecraft begins to enter a planet's atmosphere, it usually slips into a pattern of curving motions known as braking ellipses, the set of curves, each shrinking in size because of aerodynamic drag, used by the vehicle to slow itself and to dissipate the heat of atmospheric friction.

Deflector: A type of force field (which see), more frequently employed in science fiction at present than in the past. The X- and Y-wing fighters of *Star Wars* have built-in force field deflectors that can be angled to ward off enemy fire. According to *Star Trek* literature, in which capabilities have been more defined than on the TV programs, the U.S.S. *Enterprise* features two force barriers, one to sweep debris from its path, the other to protect it from all but the most powerful weapons, such as short-range photon bombs. The path-clearing deflector operates whenever the vessel moves. The defensive deflector automatically surrounds the ship when sensors and computers signal the approach of danger, whether in the form of energy or of matter. Maximum defensive shielding can be maintained for approximately 20 hours, after which the ship's power sources become drained.

Escape velocity: The minimum velocity at which a spacecraft must move in order to break away from the gravitational field of a celestial body. Since each celestial body has a different mass, each requires a different escape velocity. A speed of more than 25,000 mph is needed to pull away from the earth's restraints, but 5,292 mph is enough to zoom away from the moon's.

Exotic propulsion systems: Science fiction writers and speculative physicists have envisioned many novel methods of propulsion, all meant to do away with the need for spaceships to carry large quantities of chemical fuel. Here are five interesting concepts:

- **Bussard interstellar ramjet.** A device, proposed in 1960 by the American physicist Robert W. Bussard, which theoretically enables a spaceship to attain relativistic speeds. A magnetic scoop at the front of the ship sucks in hydrogen atoms scattered in interstellar space, funneling them into a fusion reactor which spits out a continuous jet of heated gases. Because of the limitless availability of hydrogen atoms between planets and stars a ship of this type has unlimited range.
- **ram augmented interstellar rocket.** A ramjet/rocket hybrid proposed in 1974 by the British engineer Alan Bond. Its thrust is produced by a fusion rocket that uses hydrogen isotopes (dueterium and tritium) as fuel, augmented by the electrical acceleration of magnetically scooped interstellar matter.
- **electric propulsion.** Most proposals relating to electric propulsion envisage the use of a fission- or fusion-based nuclear reaction to produce electrical energy which is then used to accelerate a stream of elementary atomic particles to extremely high velocities.
- **photon drive.** A form of propulsion in which thrust would be obtained from photons or light waves.
- **field drive.** A form of negative gravitational force field propulsion in which the spaceship's power plant "pushes" against the entire mass of the universe for acceleration.

Force field: Force fields exist in nature, as in the area surrounding a magnet. However, science fiction dreams up exotic types not yet known to present day physics. Fiction's usual force field is an invisible, impenetrable energy barrier used to keep something out, such as poisonous gas, or to keep something in, such as captives. When not used as deflectors (which see), force fields are used for propulsion. Force field propulsion systems use magnetic, gravitational, or electrostatic energy extracted from the spacecraft's environment. In TV's *Moonbase Alpha*, Eagle spacecraft use artificial gravity fields to attain 15 per cent lightspeed.

Fuel cell: The Space Shuttle Orbiter obtains electricity from fuel cells, as did all of the Gemini and Apollo spacecraft. Fuel cells produce a continuous flow of direct current electricity by the reaction of a fuel and an oxidizer. They are compact, use fuel and oxidizer relatively efficiently, and produce more power per unit of weight than other sources of electricity.

Guidance system: The electro-mechanical apparatus used to determine a spaceship's (or airplane's or guided missile's) course and to keep it as nearly as possible on a desired flight path. The guidance system (also called the flight control system) contains all of the sensors, computers, and servomechanisms needed to convert guidance commands into directional responses during the initial, midcourse, and terminal phases of operation. In *preset guidance*, a course that cannot be changed in flight is "locked into" the mechanism's computers; in *inertial guidance*, the ship's movements are measured and translated into control responses within the craft inself; in *radio guidance*, the craft responds to data received from an outside source. A spaceship may orient itself in space by following beams of radar waves, by

sensing the visible light or infrared emissions of bright stars or other celestial bodies, or by homing on signals sent from its destination. In general, nearly all of a spacecraft's guidance mechanisms are duplicated, so that if the first should fail the second takes over immediately, allowing the ship to continue its mission.

Hydrazine: A colorless, fuming, corrosive liquid (H_2NNH_2) often used as a jet and rocket fuel. The Space Shuttle *Enterprise* has a hydrazine-fueled auxiliary power unit which supplies the hydraulic pressures necessary to change several of the Orbiter's aerosurfaces in flight.

Hyperspace: A term used in many science fiction short stories, novels, and films, but brought to public awareness largely through the movie *Star Wars*. Hyperspace is a spacecraft-created tesseract or "wrinkle" in space and time: a separate and momentarily distinct space-time continuum, or local warpage, permitting instantaneous traversals of enormous distances. It eliminates normal "here to there" travel because space becomes compressed like accordian pleats and the warpage-activating craft plunges through the folds. Hyperspace travel capitalizes on supralight jumps (which see).

Impulse engine: *Star Trek*'s U.S.S. *Enterprise* is powered by impulse engines as well as by warp-drive engines (which see). The impulse engines, which serve as a secondary propulsion system, are positioned at the bottom rear of the primary hull. They're rocket devices that develop thrust by the expulsion of ignited fuel gases. Because of these engines, the primary hull reportedly can detach itself from the rest of the ship and operate independently — although this was never shown in the TV series.

Ion engine: The TIE fighters in *Star Wars* zip back and forth by means of ion engine propulsion. An ion is an atom or molecule that has lost or gained one or more electrons, rendering it electrically charged. In a TIE fighter's double ion engines, positively charged ions are accelerated to tremendous speeds by electrostatic fields, then neutralized just before being expelled through a rear nozzle. Though nuclear reactors aren't mentioned in *Star Wars*, most ionic propulsion involves the use of one or more rocket engines linked to a nuclear reactor.

Ionization: A spacecraft such as the Space Shuttle *Enterprise*, when reentering earth's atmosphere, heats air, through its friction, to very high temperatures. This extreme heat causes ionization of the surrounding air, which temporarily wipes out all radio reception or transmission. (See definition of ion under ion engine.) In addition to high temperature, ionization can be caused by chemical reactions, electrical discharges, and nuclear radiation.

Laser cannon: *Star Wars' Millennium Falcon* is equipped with laser cannons in top- and bottomside turrets; the X-wing fighter has four wing-tip laser cannons. Laser technology was perhaps foreseen by H. G. Wells, because the Martians in his "The War of the Worlds," use "swords of heat." But laser weaponry is not just science fiction fantasy; real-life hunter-killer satellites will probably use laser weaponry and laser beams have already shot down a missile in flight. "Laser" is an acronym for *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation. The term "optical maser" is sometimes used instead. Regardless, a laser beam is produced by apparatus that shifts mixed-frequency electromagnetic energy to one or more discrete frequencies of highly amplified, coherent, usually visible radiation. Because laser beams are very concentrated they can be projected for long distances with very little energy loss. At low power they can carry messages just as do telephone wires and radio waves; at high power they can vaporize plates of armor. Because they are easily aimed, travel at the speed of light, and can be made very powerful, they seem well-suited for use as space weaponry. Science fiction spaceships defend themselves from laser beams with deflectors (which see).

Lifting body technique: The shape of the Space Shuttle Orbiter body imparts much of the craft's aerodynamic lift. The Orbiter gains lift through the application of Bernoulli's Principle, which states that the pressure of a gas decreases as its velocity increases. The upper surface of the Orbiter's fuselage — like the upper surface of an airplane wing — arches skyward at the front end, while the bottom surface is almost flat. This configuration causes air to move more rapidly across the Orbiter's top than across its bottom. Air pressure is therefore less above the vehicle than it is below.

Lightspeed ship: A spaceship that travels at the speed of light: about 186,284 miles-per-second.

Mach number: A number representing the ratio of a spacecraft's speed to the local speed of sound. Sonic speed — Mach 1 — is about 760 mph at sea level (the speed of sound decreases at higher altitudes as the atmosphere becomes less dense). A spacecraft moving at five times the speed of sound is traveling at Mach 5, at ten times the speed of sound at Mach 10, and so on.

Parking orbit: The path described around a celestial body by a spacecraft which is moving at such a speed that the vehicle will maintain an endless revolution without using its engines. The spacecraft is held in orbit by the balancing forces of its centrifugal thrust into space and the downward pull of gravity. A parking orbit about the earth calls for a velocity of about 18,000 mph at an altitude of roughly 200 miles. Parking orbits are used to wait for the arrival or assembly of additional spacecraft components or to mark time while waiting for conditions favorable to departure from orbit.

Phaser: A phaser shoots a beam that kills or stuns, depending on the emission intensity. The precise nature of the emission is never explained, although the weapons figure prominently in *Star Trek*. Crewmembers of the *Enterprise* carry phaser sidearms, while the ship itself has banks of artillery-size phasers and can release proximity-fused phaser depth charges.

Photon torpedo: Not the same as a proton torpedo (which see). A *Star Trek* photon torpedo consists of a pod containing matter and antimatter temporarily separated by a magnophoton force field. A shattering detonation results when the matter and antimatter are slammed together. Photon torpedoes can be fired at a target, strewn as depth charges, or laid out in mine fields. In real-world physics, a photon is described variously as an elementary particle or packet of radiation; a discrete wave-particle entity; a virtual seed of pure energy; and as the mediator of electromagnetic interactions. A photon's energy is inversely proportional to its electromagnetic

wavelength; that is, the shorter the wavelength the higher the energy. Visible light consists of photons.

Propellant: A mixture of fuel and oxidizer, ignited and burned in a combustion chamber to produce gases which are ejected through a nozzle, causing a reaction in the opposite direction. In a liquid propellant rocket engine, fuels are in a liquid form before being pumped into the combustion chamber and the oxidizer is mixed in separately. In a solid propellant rocket engine, chemicals, which have been pre-mixed with an oxidizer, are in solid form before combustion. Several terms are frequently used with respect to propellants:

- **Composite propellant.** A solid rocket propellant consisting of a fuel and an oxidizer, neither of which will burn without the other.
- **Double-base propellant.** A solid rocket propellant consisting of two unstable compounds that react with each other without requiring a separate oxidizer.
- **Hypergolic.** Two substances are hypergolic if they ignite spontaneously when mixed together.
- **Liquid hydrogen.** Gaseous hydrogen is liquified by cooling in order to make it denser; liquid hydrogen is the lightest chemical rocket fuel and is very powerful in terms of its weight.
- **Liquid oxygen.** Commonly called LOX, liquid oxygen is often used as the oxidizer in liquid hydrogen fueled rocket engines.

Proton torpedo: Not the same as a photon torpedo (which see). X-wing fighters in *Star Wars* blast proton torpedoes from tubes flanking their fuselages. A proton is a stable, positively charged elementary particle slightly smaller than a neutron with which it is normally coupled in the nucleus of an atom. A single proton forms the nucleus of a hydrogen atom.

Sink rate: The measure of the rate of decrease of a spacecraft's altitude. The term is normally used in conjunction with *glideslope*, the angle at which this decrease is attained.

Solar cell: A semiconductor device used for the photovoltaic conversion of light energy into electrical energy. Solar cells are normally clustered on solar panels (which see). Though not as efficient as fuel cells (which see), they are independent of chemical fuels, since they're activated by the bombardment of ever-present photons.

Solar panel: A spacecraft surface or extended panel covered with hundreds or thousands of solar cells. Present day satellites use solar panels (in conjunction with nickel-cadmium battery packs) as their source of electrical energy. The TIE fighters in *Star Wars* feature two large hexagonal solar energy gathering sails which produce the electricity needed to operate the double ion engines.

Spacecraft orbits: Spaceships follow orbits, just as do planets, satellites, asteroids, and comets, because they're subject to the same laws of motion and gravitation. The difference is that a spaceship uses its own power to place itself in a desired orbit and can change to another orbit whenever desired. Because orbital motion persists with no force other than gravitation, propulsive power can be cut off for most of a spacecraft's journey, yielding great fuel savings.

Starship: A spaceship capable of interstellar or intergalactic travel.

Supralight jump: An incredible surge of velocity: the spaceship equivalent of an electron's quantum jump from one atomic shell to another. In *Star Wars*, the *Millennium Falcon* makes supralight jumps into hyperspace (which see) whenever pursued by the authorities or enemies.

Suspended animation ship: Also called a sleeper ship. Along with egg ships, which are starships piloted by robot nurses who shepherd cryogenically stored human sperm and ova, suspended animation ships have become science fiction staples. By deep-freezing their occupants, who can be periodically thawed out to take control of the spaceship, these arks can traverse space for thousands of earth years until they reach their destinations. In one episode of *Moonbase Alpha*, a suspended animation ship crash-lands on the moon. In a *Star Trek* episode, a suspended animation ship named the S.S. *Botany Bay* docks beside the *Enterprise*.

Tractor beam: Short for attractor beam. A type of force field (which see) that has become even more popular with science fiction writers than the suspended animation ship. In *Buck Rogers* comic strips of the 1930's, tractor beams were used by spaceships to anchor above planetary surfaces, but in most current science fiction the beam grabs and pulls objects to the spaceship. In an opening *Star Wars* sequence, the Rebel blockade runner is hoisted by a tractor beam—called a force beam—into the innards of an Imperial Star Destroyer. In *Star Trek* episodes, tractor beams have a range of approximately 100,000 miles, can lock the *Enterprise* beside another vehicle, and can pull smaller vessels toward the *Enterprise*.

Turbo thruster: An engine that compresses ingested air ram-jet fashion and intensifies exhaust velocities with an afterburner. *Battlestar Galactica*'s Viper intercepters achieve extreme acceleration by the use of turbo thrusters.

Warp-drive engine: *Star Trek*'s U.S.S. *Enterprise*'s main power unit consists of two cylindrical warp-drive engines (also called space warp propulsion units) in elongated outboard nacelles. These engines generate the power needed to hurl the starship forward at supralight speed (see warp factor). Each engine's energy is produced by the annihilation of matter and antimatter within a reaction chamber known as the matter/antimatter integrator. Before starting, however, each engine must be warmed up for approximately half an hour in a regenerating chamber, because matter and antimatter must never be mixed cold. Dilithium crystals are necessary for control of the mixing process. They exist in two forms—as translucent octahedrons about six inches through the longest axis and as reddish-gold translucent blocks about six-by-six-by-one inches in size. Warp-drive engines are potentially dangerous—if the nacelle shielding deteriorates, or if the engine is incorrectly cycled, the *Enterprise* might explode. For this reason the starship is constructed so that the nacelles can be blown away from the rest of the ship in an emergency. The ship then uses its back-up impulse engines (which see) to navigate to the nearest suitable landing place.

Warp factor: The speed of *Star Trek*'s U.S.S. *Enterprise* is measured in warp factors, short for space warp factors. Warp factor one is the speed of light, about 186,284 miles-per-second, or slightly more than six hundred million miles-per-hour. After warp one, each warp factor is the given number cubed times the speed of light. That is

warp two is 2 x 2 x 2 times the speed of light, or 8 times lightspeed. Warp six (normally the *Enterprise*'s highest speed) is 6 x 6 x 6 times the speed of light, or 216 lightspeeds, and so on. Warp factors seven and eight are for emergencies only. At warp eight (512 times lightspeed!) the *Enterprise*'s structure is severely stressed; warp nine—though attainable—is extremely dangerous. Most other science fiction spaceships, as in *Star Wars*, reach supralight speeds via a dual antigrav and supralight drive system. Antigrav is used to pull away from a celestial body's tug, then supralight speed is achieved through a supralight jump.

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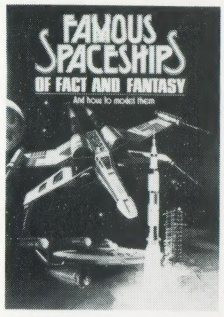

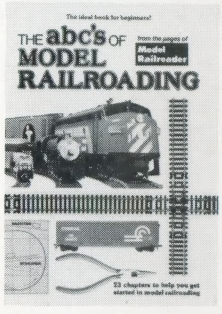

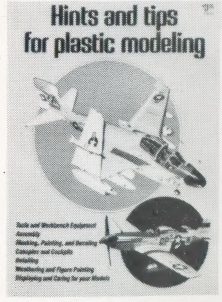

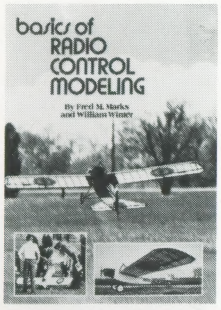

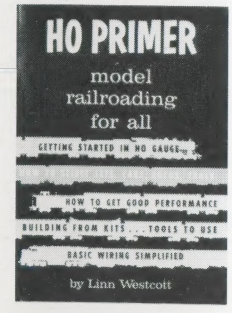

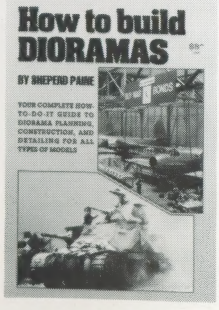

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